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The Theory of Visual Judgments in Motion and its Application to the Design of Landing Aids for Aircraft

By E. S. CALVERT, B.Sc., A.R.C.Sc.I.

Summary

This paper is intended to bring the theory of the visual aids up to date, and to discuss various practical methods of increasing the safety of the approach and landing operation.

Arguments are put forward to show that the guidance in the vertical plane needs to be improved, particularly in visibilities somewhat above the limiting visibility, and a new form of angle of approach indicator is described, which promises to achieve this result. The beam spreads of the approach lights should be increased, and fittings for providing guidance for circling approaches should be developed. The British design of flush-type runway light has proved satisfactory in actual operations, and as a result, landing mats have now become practicable, even on existing runways.

(1) Introduction

This paper takes up the story of the visual aids from the point where it was left in the paper presented in April, 1950[1]. Those who have read that paper will, perhaps, remember it for two things. One is the demonstration that an observer in a free-moving framework cannot, by looking at the ground, separate lateral error from bank, unless the picture which he sees includes an indication of the horizontal derived either from the real horizon or from bars transverse to the path which he desires to follow. All present-day ground patterns make use of this principle, and it is now generally accepted. The other thing which readers of the previous paper may remember is the parafoveal streamer theory of visual judgments in motion. At that time we had not worked out all the implications of this theory, the chief of which is that the streamer pattern provides the rate information which is necessary for stability, i.e. for holding a straight track. The first part of the present paper will therefore be devoted to explaining how rate information is derived from the visual field, and its importance for safety. The second part of the paper will describe some proposed additions to the existing patterns, and give some basic data which should assist lighting engineers to decide on the beam spreads required from the fittings.

(2) The Present Problem

When the present patterns of visual aids were being developed 10 years or so ago, the emphasis was on bad weather landings, i.e., the usefulness of high intensity approach lights was considered to lie almost entirely in the fact that they permitted landings to be made in lower meteorological visibilities. This is still the most important reason for using approach lights, but operational experience has since shown that another, and almost equally important, reason is that a properly designed system increases safety in the better visibilities when it might have been supposed that no approach lights were necessary. Indeed the fact is that during the past five years, nearly all the civil accidents which have been attributed to visual misjudgments (pilot error) at landing have occurred when the visual range was considerably above the

The author is with the Ministry of Supply Royal Aircraft Establishment. The manuscript of the paper was received on March 11, 1957. The paper was presented at a meeting of the Society held in London on April 9, 1957.

minimum, in many cases more than three miles.* None of these accidents occurred on a runway on which the full crossbar approach lighting system was installed, in spite of the fact that the majority of instrument approaches made by British civil aircraft were on runways which did have this pattern. It is, however, a moot question whether the low accident rate on the crossbar system will continue with future types of aircraft, because with each new project there is a strong incentive to increase the instrument approach speed in order to take advantage of the reduced operating costs to which this leads. This reduction is substantial, being estimated to be in some cases proportional to the increase in approach speed. In a competitive world, instrument approach speeds are therefore almost certain to rise, in the hope that any reduction in safety due to the increase in speed will be offset by improvements in the various approach and landing aids. With visual aids we have already reached the point where additions to the pattern are beginning to pay diminishing returns, and it seems that when the additions discussed in this paper have been incorporated, the only hope of further substantial improvements will be in other directions. To see why this is so, it is necessary to examine the nature of the pilot's task, and the kind of information which he needs to do it.

(3) The Pilot's Task in Landing

Most of us drive cars, and if asked how we follow a desired track, would probably reply that we do it by noticing how far we are at every moment from the path. This answer, although it is true to the extent that we do need displacement information, is based on a picture of the control process which has to be corrected and amplified before we can visualise what the process of driving a vehicle really is. This may be shown by considering what happens in a fog when a passenger in a vehicle tries to guide the driver by continuously telling him how far away he is from the kerb. In this situation the vehicle weaves from side to side across the road, the amplitude of the oscillations depending not only on the skill of the driver, but also on the quality of the information supplied by the passenger. In other words, the driver will do better with an intelligent passenger who puts some phase advance into the information than he will with a slow-witted one who brings it out a second or two late. The true picture is that oscillations about the desired path are always present, but are reduced to very small limits when the driver is supplied with *two* other pieces of information in addition to his displacement. The first piece of information is his track heading relative to the desired path, i.e., the angle between the tangent to his track and the desired path; the second is the rate of turn, i.e., the rate of change of track heading. This is illustrated mathematically in Fig. 1 for a single plane.

For a given speed the relative track heading, γ, is proportional to the first derivative of the displacement, and also to the rate of closure with (or departure from) the desired path. Information about γ is therefore known as "rate information." The rate of turn is proportional to the second derivative of the displacement, and information about it is known as "rate-rate information." For those who prefer a non-mathematical description, the fact that the driver should have information about displacement, rate of closure and rate of turn may be expressed by saying that he should know where he is at any moment, where he is going at that moment, and also be able to anticipate where he will be going a few moments later. When he moves the steering wheel, he produces a rate of turn which in time produces a certain change in heading, which in time produces a certain change in displacement. The process of correcting an error consists in matching heading against displacement, so that at the moment when the displacement eventually becomes zero, the relative track heading and the rate of turn have also become zero.

These three quantities appear as changes in the driver's visual environment, and

* In a recent investigation about 95 per cent. of the combined undershoot and overshoot accidents due to visual misjudgments occurred when the ceiling was more than 1,000 feet, and the visibility more than 3 miles.

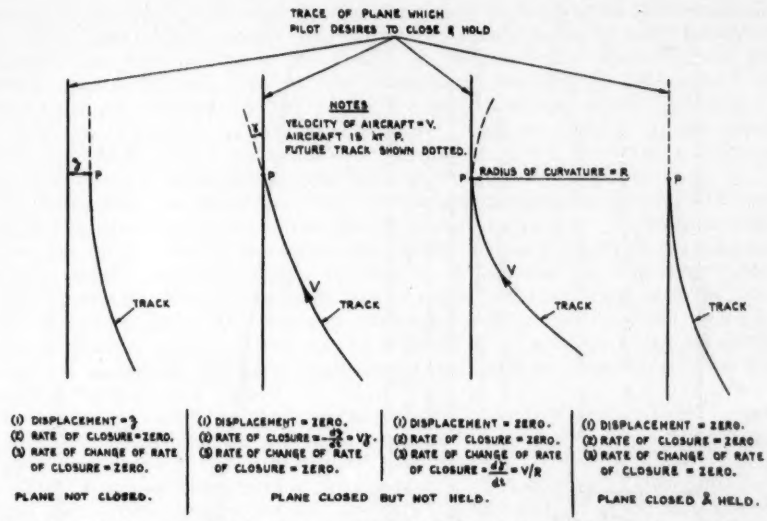

TRACE OF PLANE WHICH
PILOT DESIRES TO CLOSE & HOLD
NOTES
VELOCITY OF AIRCRAFT = V.
AIRCRAFT IS AT P.
FUTURE TRACK SHOWN DOTTED.
RADIUS OF CURVATURE = R
P
V
TRACK
(1) DISPLACEMENT = ?
(2) RATE OF CLOSURE = ZERO.
(3) RATE OF CHANGE OF RATE OF CLOSURE = ZERO.
PLANE NOT CLOSED.
(1) DISPLACEMENT = ZERO.
(2) RATE OF CLOSURE = -dr/dt = V?.
(3) RATE OF CHANGE OF RATE OF CLOSURE = ZERO.
(1) DISPLACEMENT = ZERO.
(2) RATE OF CLOSURE = ZERO.
(3) RATE OF CHANGE OF RATE OF CLOSURE = dV/dt = V/R
PLANE CLOSED BUT NOT HELD.
(1) DISPLACEMENT = ZERO.
(2) RATE OF CLOSURE = ZERO
(3) RATE OF CHANGE OF RATE OF CLOSURE = ZERO.
PLANE CLOSED & HELD.

Fig. 1. Diagram illustrating three conditions which must be simultaneously satisfied in order to close and hold a desired plane.

there is a feedback of information from this environment to the driver which modifies his behaviour. As with any control with feedback, i.e., any servo system, we have to put up with deviations from the desired value, since it is precisely these deviations which are employed to execute the necessary corrections. If the time delay associated with the feedback of information is large compared with the time taken for a control movement to take effect, continuous oscillations with large deviations can result. The greater these delays, the greater the skill required from the human links in the servo loop. Systems of control employing feedback are widespread in nature and society, as well as in industry, and their study is known as cybernetics, i.e., the study of control and communication. It is an interesting thought that the principles of "automation" and the visual control of a moving vehicle are fundamentally the same. It should be remembered, however, that the above observations refer to the control of a vehicle in situations already recognised for what they really are, i.e., in the case of an aircraft, illusions are assumed to have been prevented by the use of texture, crossbars, etc., as described in the previous paper and elsewhere.(2)

We have examined this aspect of visual guidance at some length because, when visual aids are discussed, the discussion almost invariably proceeds on the assumption that only displacement information is necessary, and as this assumption is tacit and usually unconscious, nothing one can say has much effect, particularly when one's observations have to be translated into another language. Even some of those who have studied cybernetics in connection with other problems fall into this error when they come to consider visual guidance. The psychologists working on visual perception are particularly prone to it and habitually discuss visual guidance in terms of about a dozen different "clues," failing to distinguish between those required for recognition and those required for guidance and control. Following a practice not uncommon in other fields of psychology, they have added to the confusion by adopting a bad terminology and by misusing terms such as "parallax" and "orientation" which they have borrowed from the physical sciences without understanding their technical

HORIZON
V
RUNWAY AT BEGINNING OF TIME INTERVAL
RUNWAY AT END OF TIME INTERVAL.
HOR. TRACE OF PLANE IN WHICH AIRCRAFT IS ACTUALLY DESCENDING DURING TIME INTERVAL.
HOR. TRACE OF SLOPE ON WHICH AIRCRAFT IS LOCATED AT BEGINNING OF TIME INTERVAL.
HOR. TRACE OF SLOPE ON WHICH AIRCRAFT IS LOCATED AT END OF TIME INTERVAL.
PILOT BRINGS X ON TO INSTANTANEOUS POSITION OF A AT MOMENT WHEN AV IS EQUAL TO THE ANGLE OF THE GLIDE SLOPE, OR IS WITHIN ACCEPTABLE LIMITS; AFTER WHICH AV REMAINS CONSTANT.
AIRCRAFT IS OVERSHOOTING THE AIMING POINT, A, WHICH IS THEREFORE MOVING AWAY FROM THE HORIZON AT A RATE DETERMINED BY MAGNITUDE OF ANGULAR DISTANCE XA. AT ANY GIVEN RANGE & SPEED, XA IS PROPORTIONAL TO THE RATE OF CHANGE OF THE ANGULAR DISPLACEMENT, AV, i.e. $d\alpha/dt = V/R\,(\alpha-\beta)$, WHERE V=SPEED & R = RANGE.
EFFECT OF ABSENCE OF HORIZON
IF HORIZON IS NOT VISIBLE, THEN AV CAN ONLY BE ESTIMATED BY RECOLLECTING HOW HIGH A SHOULD BE ABOVE THE CUT-OFF LINE BB. ANGULAR DISTANCE OF A ABOVE BB VARIES WITH PITCH ATTITUDE, HEIGHT OF AIRCRAFT, DRIFT ANGLE, HEADING ERROR, SPEED, BANK ANGLE & POSITION OF PILOT'S HEAD RELATIVE TO WINDSCREEN. DISPLACEMENT & RATE OF DESCENT INFORMATION ARE THEREFORE CONFUSED, PARTICULARLY DURING THE CORRECTION OF A LATERAL ERROR.
LIMIT OF PILOT'S DOWNWARD VIEW (CUT-OFF LINE)
B
B

Fig. 2. Perspective views of runway during an approach.

meaning.[3] The explanation may be that our habits of thought on this matter (in so far as we think about it at all) have been formed early in life by our experiences in walking about the surface of the earth. In this case rate information is not important because the speed is low and because we can change displacement by stepping aside, i.e., without applying a rate of turn, and waiting till this produces its train of effects. However, as soon as one starts to learn to drive a car, one has to learn to stop looking at the side to see what the displacement is and learn to fixate on a point well ahead in order to see what the track heading is.

An interesting example of the results of thinking in terms of displacement only is provided by the slopeline system described in the previous paper. Here the inventor tried to solve the problem of guidance in the vertical plane by improving the displacement information, whereas the real problem is to improve the rate information. Actually the rate information was made slightly worse by the convergence of the lines, and for this and other reasons the system had eventually to be discarded. It might, perhaps, help us to get rid of this way of thinking if we remember that we match displacement and rate of change of displacement every time we raise a cup to our lips or adjust a reading on a meter.

Having grasped the importance of rate information and the fact that the control process is one of matching, the next thing to realise is that an aircraft is a very special type of vehicle, in that it has six degrees of freedom and is controllable about all three axes. This is very different from a surface vehicle which has only three degrees of freedom and is controllable about only one axis. In bad visibility these extra degrees of freedom confuse the visual indications in ways of which the person who has driven only a surface vehicle has no conception; it is because of this that we at R.A.E. have had to build a simulator[4]. To understand the details of how corrections are made in two planes, the vertical and the horizontal, involves a fair knowledge of perspective, and a considerable effort of the imagination, so this paper will give only the overall results of the research. Those who wish to go into the matter more deeply will find a detailed description in one of the references already given[2].

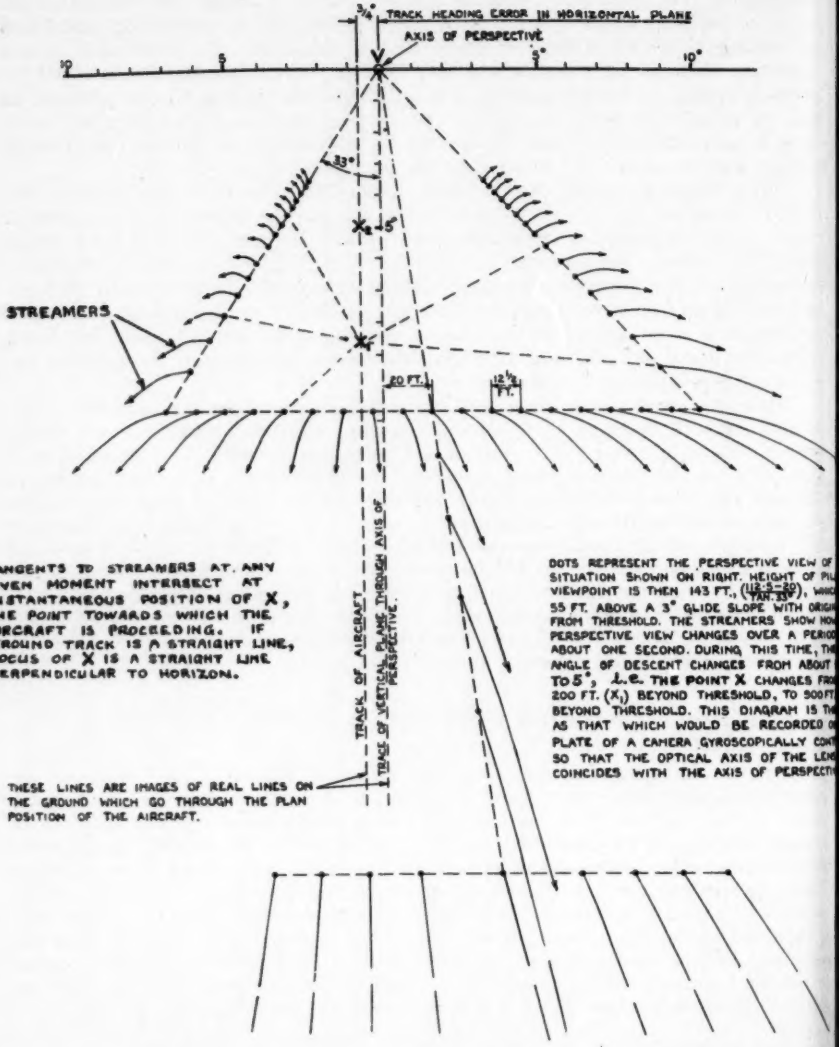
(4) How Information is Obtained from the Visual Environment

(4.1) Displacement Information

The two displacements (one for each plane) are given by the *shape* of the perspective image, i.e., a photograph taken at any moment would show the displacements at that moment. For instance, the lateral displacement of an observer with respect to a line on the ground is zero if the image of that line appears to him to be perpendicular either to the horizon or to a cross-bar. This is illustrated in Fig. 2, where it may be seen that the centre line of the runway is perpendicular to the horizon. What is less well known is that in the vertical plane, the displacement from the desired path is indicated by the aiming point, A, not being at the desired angular distance below the horizon. In bad weather the aiming point, when it comes into view, should appear below the horizon at an angle equal to the angle of the glide path. If it is nearer the horizon the aircraft is low, and if it is further away, the aircraft is high.

(4.2) Rate information

This is given by the position of the origin, X, of the streamer pattern in the perspective picture. (X is, of course, the point in the picture towards which the aircraft is actually proceeding.) The rate in the horizontal plane is the apparent horizontal distance between the vanishing point of the centre line and a vertical line through X. In the vertical plane the rate in which the pilot is interested at heights above about 100 ft. is given by the apparent vertical distance between X and the desired aiming point, A. At heights below about 100 ft. the pilot is increasingly interested in his rate of closure with the ground, and this is given by the vertical distance of X below the


TRACK HEADING ERROR IN HORIZONTAL PLANE
AXIS OF PERSPECTIVE
STREAMERS
20 FT.
TRACK OF AIRCRAFT
TRACE OF VERTICAL PLANE THROUGH AXIS OF PERSPECTIVE.
TANGENTS TO STREAMERS AT ANY GIVEN MOMENT INTERSECT AT INSTANTANEOUS POSITION OF X, THE POINT TOWARDS WHICH THE AIRCRAFT IS PROCEEDING. IF GROUND TRACK IS A STRAIGHT LINE, LOCUS OF X IS A STRAIGHT LINE PERPENDICULAR TO HORIZON.
THESE LINES ARE IMAGES OF REAL LINES ON THE GROUND WHICH GO THROUGH THE PLAN POSITION OF THE AIRCRAFT.
DOTS REPRESENT THE PERSPECTIVE VIEW OF SITUATION SHOWN ON RIGHT. HEIGHT OF PILOT'S VIEWPOINT IS THEN 143 FT., (112·5 − 50 / TAN. 3°), WHICH IS 55 FT. ABOVE A 3° GLIDE SLOPE WITH ORIGIN 50 FT. FROM THRESHOLD. THE STREAMERS SHOW HOW THE PERSPECTIVE VIEW CHANGES OVER A PERIOD OF ABOUT ONE SECOND. DURING THIS TIME, THE ANGLE OF DESCENT CHANGES FROM ABOUT 3° TO 5°, i.e. THE POINT X CHANGES FROM 200 FT. (X1) BEYOND THRESHOLD, TO 900 FT. BEYOND THRESHOLD. THIS DIAGRAM IS THE SAME AS THAT WHICH WOULD BE RECORDED ON A PLATE OF A CAMERA GYROSCOPICALLY CONTROLLED SO THAT THE OPTICAL AXIS OF THE LENS COINCIDES WITH THE AXIS OF PERSPECTIVE.

horizon. A photograph taken from the cockpit with a camera controlled to "look" at the vanishing point, V, would, if a long exposure were used, enable the rates to be obtained by virtue of the fact that the lights would appear on the photograph as lines, to which the tangents at any moment would pass through X. This is shown in Fig. 3. This, as explained in the previous paper, is one reason why the driver of any fast-moving vehicle keeps his head still and stares fixedly in a constant direction in space, which is normally close to the direction in which he is going. It is clear that in order to find X at all there must be numerous objects in the field of view, and the streamer

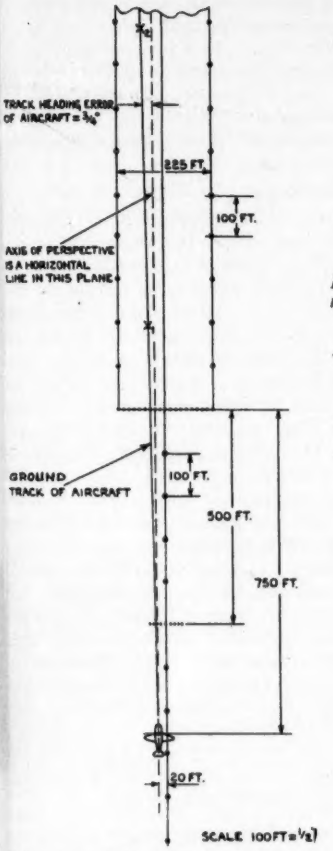


Fig. 3. View of runway showing how pilot obtains rate information.

Plan view of situation shown on left.

velocity within a certain angular distance from X must be above a certain value. Since the streamer velocity decreases as the height increases, there is some height above which rates cannot be obtained from the visual field. It follows that an observer in a glass sphere without any marks on it to tell him where it is pointing, could not see from the visual indications what changes in the direction of motion were taking place in response to the movements of the control, unless these movements were very large. In fact he would not know, merely from looking out, whether he were going forwards or backwards, upwards or downwards. In the real case a pilot is always surrounded by a framework, and is able to *deduce* where the aircraft is going by the relationship of this framework to the horizon, by his knowledge of the control configuration and by the readings of the instruments. The relationship of the framework to the horizon is known as the "attitude" and its significance lies, of course, in the fact that except at very low speeds, an aircraft goes in a direction close to that in which it is pointing, i.e., attitude is normally a good indication of rate. Attitude information is greatly

improved if the cut-off line of the cockpit cowling is horizontal, and this feature is already being incorporated in at least one new British airliner.

(4.3) Rate-Rate Information

This is given by translatory movement of the whole perspective picture relative to the framework, this motion being superimposed on the streamer flow produced by the forward motion. It follows that the pilot would confuse this indication by moving his head. This is the second reason why he keeps his head still. In the horizontal plane the rate-rate is proportional to the angle of bank.

(5) The Implications for Safety

The point which it is important to notice in the above theory is that crossbars can replace the horizon almost completely as regards guidance in the horizontal plane, but not nearly so completely in the vertical plane. If the horizon is obscured by rain, low cloud or mist, or if there is no horizon at all due to mountainous terrain or the absence of extraneous lighting at night, then guidance in the vertical plane is disrupted to a greater or lesser extent, depending on the number and spacing of the crossbars, and on the visual range. If the only crossbar is the line of threshold lights, then guidance in the vertical plane may be very seriously disrupted at night in visual ranges up to several miles. The reason why accidents occur in these conditions is simply that the pilot tends to leave his instruments soon after he sees the lights, because he can then begin his final azimuth correction. This means, however, that he is without adequate guidance in the vertical plane for a much longer time than he would be if he were landing in worse visibility on a runway equipped with a full crossbar pattern. With this pattern, if the aircraft is going into the ground, i.e., has a wrong vertical rate, the foreshortening of the apparent intervals between the bars and the increasing streamer velocity warn the pilot of his danger at a height of about 100 ft. This warning is quite definite and seems to occur suddenly at the moment when the point X comes into view. So far the warning time has been sufficient to prevent accidents, but in view of the tendency towards increased approach speeds, and for other reasons, this situation cannot be regarded as entirely satisfactory. Every effort therefore is being made to improve visual guidance in the vertical plane. The most promising development so far is an improved type of angle of approach indicator, because this is effective in just those conditions in which accidents are most likely to occur, i.e., moderate visibilities and no effective approach lighting. A string of lights along the centre-line without any crossbars adds little if anything to the guidance in the vertical plane and is not regarded as an effective means of preventing undershoots.

(6) The New Angle of Approach Indicator

The indicators used in the past had three sectors, the top being yellow, the middle green, and the bottom red. The indicator was located at the desired touchdown point, with the green sector pointing along the desired approach path; and the pilot was supposed to keep in this green sector. This type of indicator had the following disadvantages, the first two of which are important :—

(1) As the aircraft got closer to the runway the sector got narrower till finally the pilot could no longer keep in it. After that the aircraft might enter either the yellow or the red sectors, but as this did not mean that he was outside acceptable limits, he ignored the indication from then onwards.

(2) A single indicator, or a pair of indicators, one on each side, was not sufficiently distinctive. Indeed all the other lights were usually brighter than the indicator. In this connection it should be remembered that at the ranges at which the indication is required, the vertical subtense of the whole pattern is only about 1 deg., and that some of these lights will be red obstruction lights.

(3) The indicator was small and the setting could be inadvertently upset without the knowledge of the ground staff.

(4) Over a small angle between the red and green sectors the signal appeared the

same as over a small angle between the yellow and green sectors. The pilot was therefore liable to change pitch in the wrong sense just as he passed out of the green sector. Condensation on the lens produced a similar mixing of the colours.

(5) Failure of the single light source caused the indication to disappear.

All these disadvantages can be removed by using a pair of two-sector indicators made up of units of the type shown in Fig. 4. In the installation now under test, one indicator is located 500 ft. from the threshold and the other 1,500 ft. from the threshold. The first is set with the dividing line between the sectors at an angle of 2½ deg. above the horizontal, and the second with the dividing line 3 deg. above the horizontal. The upper sector of each indicator is white and the lower red, so that the pilot sees

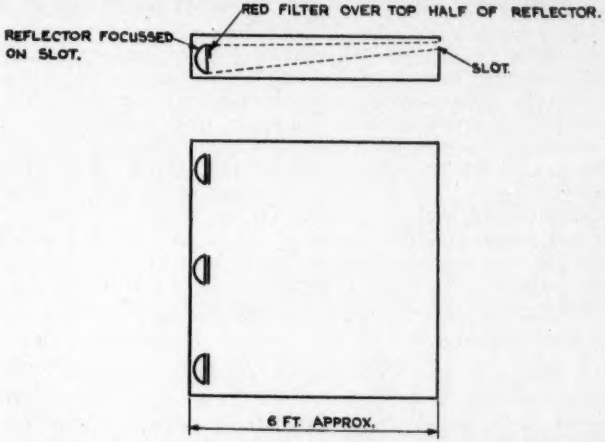


Fig. 4. Unit for Angle of Approach Indicator.

two white signals, or a red and a white, or two red signals according to which region he is in. With this arrangement the region in which the furthermost indicator appears red and the nearer one white has a width of 52.5 ft. + ½ deg. which is wide enough at the lower heights for the pilot to be able to stay in it right down to the concrete. Both the intensity and the size of the indication can be made as large as desired at small cost merely by using several units together. Flight tests have shown that the signals are interpreted instantly and instinctively.

(7) Additions to the Ground Pattern

(7.1) Marking the Aiming Point

At present the pilot maintains a constant angle of approach by keeping the threshold lights at a constant apparent distance below the horizon, when there is a horizon. It is now agreed that a point 1,000 ft. up the runway should be marked so that the pilot can keep this at a constant angle below the horizon instead of the threshold, thereby reducing the risk of an undershoot. This mark also provides a fixation point for the eye close to the point X which probably makes it easier to judge the rate. If there is no horizon, the pilot will try to fly so that the interval between the threshold and the aiming point marking appears to him to maintain a constant ratio of height to width. This is not a good indication, but where there is no approach lighting or angle of approach indicator, it may in certain circumstances be the only visual indication of angle of descent which the pilot has.

(7.2) Minimum Approach Pattern for All Runways

Since bars of lights in the approach path improve the vertical rate information by giving a better streamer pattern and improve the height information by the fore-

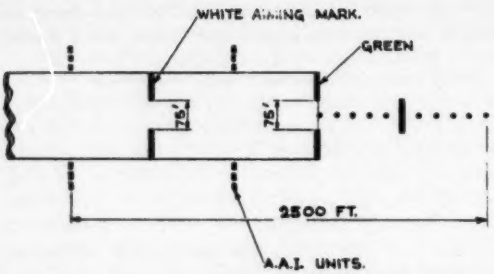


Fig. 5. Proposed minimum pattern. (Bars spaced 500 ft. apart).

shortening of the apparent intervals between the bars, it has been proposed that all runways shall have a red bar 200 ft. short of the bar of threshold lights, and that, where the terrain permits, shall also have a line of lights 200 ft. apart extending for 1,400 ft., and with a crossbar 1,000 ft. from the threshold bar. This means 4 bars (counting the aiming point mark) and to that extent it is an advance, but unfortunately the spacing between them is 800, 200 and 1,000 ft. This is the kind of unhappy compromise which emerges when an international body attempts to combine patterns which are not really compatible. If the pilot is to receive a warning that he has a wrong rate at a height as great as 100 ft., as mentioned in (4.2) above, then the bars must be at *regular* intervals of 500 ft. as in the full crossbar pattern. Fig. 5 shows the pattern of this type. It should be noted that the wing bars at 500 and 1,500 ft. from threshold are the angle of approach indicator units.

(7.3) Landing Mat

Pilots have always complained of the lack of guidance at night once the threshold lights disappear under the cut-off line of the cockpit cowling. This occurs at a height of about 75 ft., and the subsequent lack of guidance is particularly exasperating to the pilot because it is about the point where he is preparing to begin the flare-out. This is known as the "black hole effect" and is largely due to the absence of objects in the field of view sufficiently close to the point X to produce a good streamer pattern. The indications of height and rate of closure with the ground are therefore poor just at the moment when they are most needed for a good touch-down. This will become more important in the future when automatic approach, and eventually automatic land-

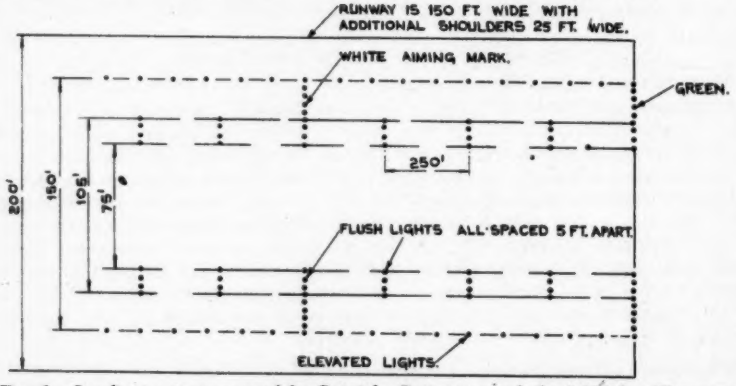


Fig. 6. Landing mat as proposed for Gatwick. Pattern extends for 3,000 ft. (Transverse scale is five times the longitudinal scale).

ing, become common, because however reliable the couplers are, the pilot will always want to monitor the landing visually if the visual range permits, as it nearly always will. It is therefore proposed that a pattern, such as shown in Fig. 6, should be installed in the actual surface of the runway, and the first such installation will be on the new runway at Gatwick. A pattern of this kind was proposed[5] as early as 1947 when it was called a "landing mat." In the marginal conditions the mat will not be seen above about 100 ft., so it will have no effect on the operating limits until automatic landing comes into use. Until that time it must be regarded as a safety device for night landings.

(8) Other Means of Improving Safety in Near-Marginal Conditions

If the new Angle of Approach Indicator is used in combination with the patterns described above, then an acceptable level of safety should be ensured for some years to come. The A.A.I. will not, however, be effective in near-marginal conditions, and so long as landings are made visually there will, in these conditions, be an element of danger below the height at which the pilot "goes visual" due to the inadequacy of the rate and displacement information in the vertical plane at heights above about 100 ft. This danger is most marked in fog conditions in which the slant range decreases as the aircraft gets closer to the ground. This seems to indicate that it is due to the fact that the eye has no point on which to fixate and keeps jumping from light to light as each comes into view. To eliminate this danger it is necessary to provide far better rate information than can possibly be obtained from any ground pattern. The only way of doing this visually seems to be by means of an optical sighting device in the cockpit, so arranged that when the pilot looks out he sees a transverse line and a dot, the dot being at glide path angle below the horizon, and the line coincident with the trace of the plane in which the aircraft is proceeding. A device of this kind has been demonstrated on the landing simulator (second model) built by J. W. Sparke in 1955. The device is very effective in the really bad visibilities, particularly with the less experienced pilots, but it is, perhaps, a little distracting at first in the better visibilities. The practical difficulties of installing this device in existing types of aircraft are probably insurmountable, but it is possible that the principle will be used in some future projects.

(9) Vertical Beam Spread from Approach Lighting Fittings

In the past the spreads were determined by taking the region of guidance laid down by I.C.A.O.[6], and assuming some limiting visual range which was usually either 1,500 or 2,000 ft. The longer range, 2,000 ft., gives a total spread of 9 deg. vertically, within which the intensity is required to be uniform in the lower 6 deg. This also leads to settings in which the lower part of the beam has elevations varying from ½ deg. for the innermost lights to 3 deg. for the outermost lights, in a pattern 3,000 ft. long. The beam spreads of the approach lights used in this country are a little narrower than this but the settings approximate to those given above, and the general result has been reasonably satisfactory. In some countries, however, a range of 1,200 ft. was assumed in setting the lights, and the axes of the beams were set at elevations varying from 5½ deg. for the innermost lights, to 12¾ deg. for the outermost, although the vertical spread was narrow. The result was that the aircraft did not enter the beams till it was almost over the outer end of the pattern. In some of these installations condenser discharge lamps were installed in addition to the fixed lights; as these had a much larger vertical spread the pilots found that they saw them at a substantially greater range than the fixed lights. They therefore concluded that flashing lights had peculiar advantages for fog penetration which lighting engineers, with their academic attachment to Blondel-Rey, had missed. Arguments are still going on, but practical experience has won the day, and condenser discharge lamps are

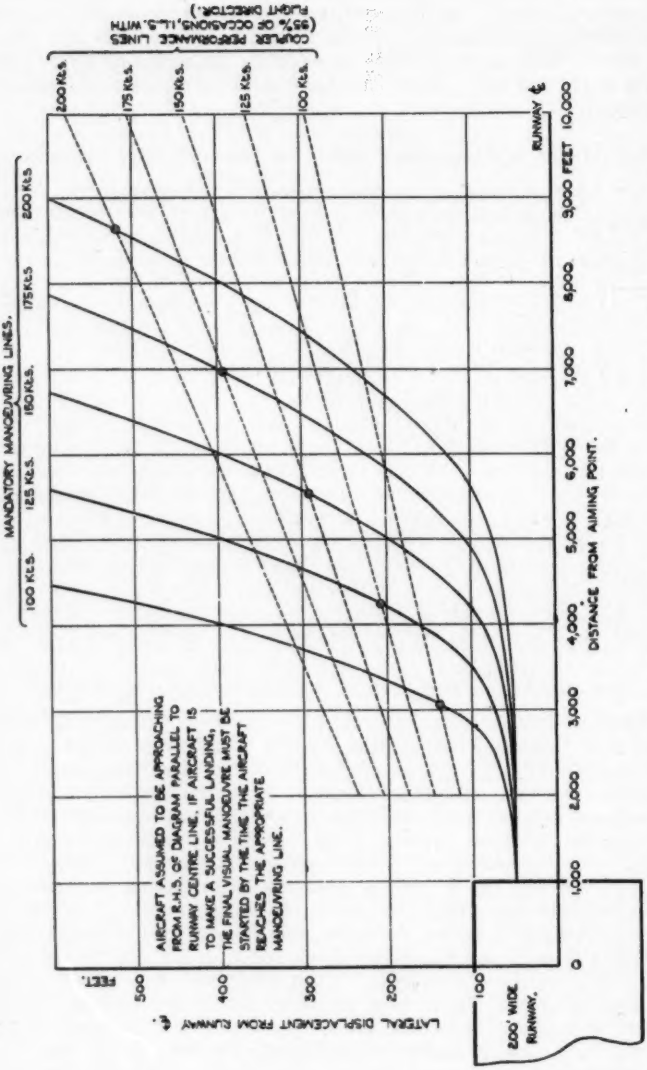


Fig. 7. Curves showing point on approach where visual manoeuvre must start to achieve 95 per cent. landing success with I.L.S. flight director.

now part of the standard system used in the U.S. Lower settings and wider beams are, however, being used in the U.S., e.g., the sealed beam lamp PAR56, and it will be interesting to see whether this leads to a reappraisal of the condenser discharge lamps. As the crossbars in the U.S. system are only 14 ft. wide, it may be that these lamps will be retained in the outermost portion of the pattern for identification purposes in built-up areas.

Once it is realised that approach lights are necessary for safety in the better visibilities it becomes apparent that the bottom part of the beam must not be set at an angle higher than the angle of the glide path. Suggested settings for this lower limit are 1 deg. above the horizontal for the innermost third of the pattern, 2 deg. for the middle third, and 3 deg. for the outermost third, which is very close to those already used in this country. Since cut-off angles of the order of 18 deg. are not uncommon in modern transports, a total vertical spread of 15 deg. is required, but the intensity can, of course, taper off to a few per cent. of maximum intensity over the upper 5 deg. With this spread, and the settings suggested above, the system performs satisfactorily when dimmed, and also in the event of an incipient undershoot.

(10) Region of Guidance in Horizontal Plane

The region of guidance depends on two things, the lateral errors at the end of the instrument portion of the approach, and the latest point in the approach at which the visually controlled final manoeuvre must begin. In Fig. 7 the full lines show the errors which will be exceeded in only 5 per cent. of approaches made on the Instrument Landing System (I.L.S.) with a flight director, for various approach speeds between 100 and 200 knots. The dotted lines are the *loci* of the latest points in the approach at which the final manoeuvre must begin if the errors are to be corrected before the flare-out and without using manoeuvres more violent than the airline pilot is willing to make. (These are called the "mandatory manoeuvring lines.") Both sets of lines have been found by analysing the results obtained in a large number of approaches with different pilots and types of aircraft and can be taken as typical of propeller-driven transports. The intersection of the pair of lines relating to a given speed gives the points (marked with small circles) where visual guidance must be available to the pilot if he is to have a 95 per cent. chance of getting on the runway with an acceptable final manoeuvre. Starting from the points marked with the small circles, we can then draw the track of the aircraft for any given approach speed when the lateral error is on the limit for getting on the runway. One such track is shown chain dotted in Fig. 8, this being for a speed of 125 knots. If we draw similar tracks for various speeds and take their envelope, as shown in full line, the resulting funnel-shaped figure is the region of guidance for an approach success rate of 95 per cent. with manual I.L.S. and flight director. The region of guidance for manual I.L.S. with cross-pointer meter is about twice as wide, and that for automatic I.L.S. about

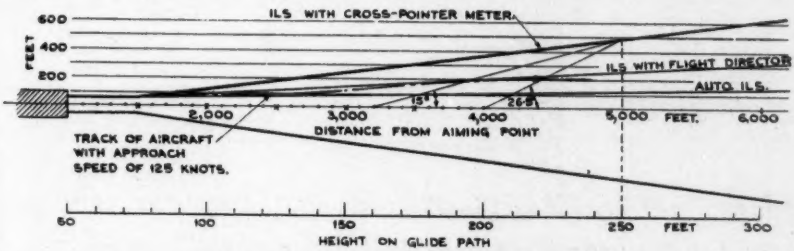


Fig. 8. Region of guidance in horizontal plane.

half as wide. The width of the I.C.A.O. region of guidance at 3,000 ft. from threshold is ± 250 ft., which is substantially narrower than that required for manual I.L.S. with cross-pointer meter.

(11) Standard Visual Pilot

During the past five years the records of many thousands of instrument approaches have been studied and numerous tests made on the R.A.E. landing simulator. These tests, combined with a consideration of the minimum visual ranges which have been found to give acceptable levels of safety in actual operations, have enabled us to set up a set of curves giving the visual range required for guidance at any given height and with any given angle of cut-off. We call this a "standard visual pilot." The S.V.P. for a glide slope of 1 in 20 and crossbar pattern with the bars 500 ft. apart, is shown in Fig. 9. If the pattern is 3,000 ft. long, the boundary curve (3) is used. If the pattern is 1,500 ft. long, curve (2) is used, and if there is no approach lighting at all, curve (1) is used. As an example, one of these guidance curves, that for a nominal cut-off angle of 15 deg. (effective cut-off 13½ deg.) has been drawn separately in Fig. 10 for a pattern 3,000 ft. long. Dotted lines have been added to this showing the obscured area and the range of the outermost end of the pattern. From these it can be seen that the length of the visual segment, S, required for guidance has been taken as 800 ft. at heights around 250 ft., and as 1,000 ft. at heights around 120 ft. This is the segment which is always in view even though the aircraft in the course of a correcting manoeuvre changes pitch by 1½ deg. in the nose-up sense.

(12) Horizontal Spread from Approach Lighting Fittings

In order to ensure safety in landing it is the practice in airline operations to lay down, for each particular set of circumstances, a height, known as the "critical height," below which the aircraft must not descend unless the pilot has adequate visual guidance. For an aircraft with manual I.L.S., landing on a runway with a crossbar pattern 3,000 ft. long, the lowest critical height used in this country is 250 ft. From Fig. 9 the visual range required for guidance is 1,800 ft. for an aircraft with a cut-off angle of 16 deg.

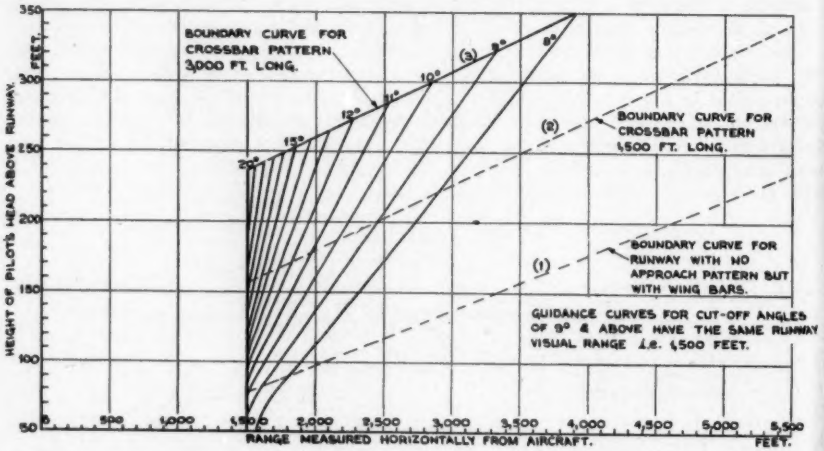


Fig. 9. Guidance curves for nominal cut-off angles of 8 deg. and above. (Glide path 1 in 20 (2.86 deg.); wing bars and crossbars 500 ft. apart.)

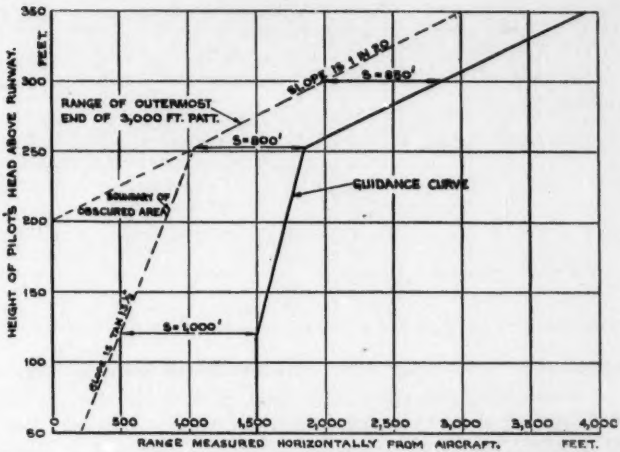

HEIGHT OF PILOT'S HEAD ABOVE RUNWAY. FEET.
RANGE MEASURED HORIZONTALLY FROM AIRCRAFT. FEET.
RANGE OF OUTERMOST END OF 3,000 FT. PATT.
S=800'
S=850'
S=1,000'
GUIDANCE CURVE
BOUNDARY OF OBSCURED AREA
SLOPE IS 1 IN 20
SLOPE IS 1 IN 13.5

Fig. 10. Guidance curve for nominal cut-off angle of 15 deg. and pattern 3,000 ft. long. (Glide path 1 in 20 (2.86 deg.); R.V.R. 1,500 ft.; effective cut-off 13.5 deg.)

or better. From Fig. 8 it may be seen that this means that to cover the region of guidance for manual I.L.S. with cross pointer meter, the beam must have a uniform intensity over about ±15 deg. from the centre line, falling to a few per cent. of maximum intensity at an angle of ±26.5 deg. from the centre line. The spreads used at present are considerably less than this, which means that in a proportion of the approaches made on manual I.L.S. with cross-pointer meter the aircraft will have to go round again or divert in visibilities in which it could have landed had the beams been wider. From the point of view of safety, as well as traffic control, this is undesirable, and there is therefore a good case for widening the beams. Another reason is that this would improve the guidance during the turn-in from a circling approach. This is also a reason for using the same horizontal spread throughout the approach lighting pattern.

(13) Lights for Circling Approaches

The term "circling approach" has become rather a misnomer because the aircraft now does a "Standard Square Circuit" which is a rectangle with rounded corners. A typical circuit, taken from a paper by Capt. P. E. Bressey, is shown in Fig. 11. Some directional types of runway lights are designed to emit some light in directions to the side, but this is practically useless because in the visibilities in which circling approaches can be made the runway lights have to be dimmed. It is obvious that the best way of providing guidance for circling approaches is to use lights facing outwards with a spread of, say, 170 deg. in azimuth, and supply these from a separate circuit. If this were done only directional runway lights would be required whatever

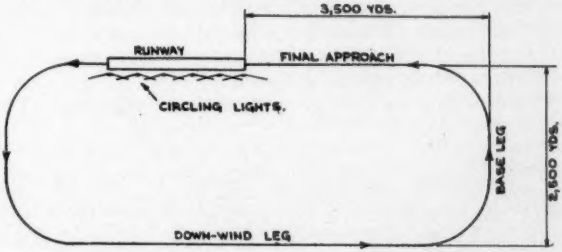


Fig. 11. Standard square circuit.

the type of runway. These circling lights might be spaced at intervals of about 1,000 ft. down each side of the runway.

C. A. Douglas, of the U.S. Bureau of Standards, has suggested that over an angle in elevation of from 2 to 8 deg., the intensity distribution in azimuth should be as follows :—

Azimuth Angle (degrees)	Minimum intensity
5 to 10 } 170 to 175 }	1,000 candelas
10 to 30 } 150 to 170 }	5,000 ,,
30 to 40 } 170 to 150 }	1,000 ,,
40 to 60 } 120 to 140 }	800 ,,
60 to 120	600 ,,

(14) New Types of Flush Runway Lights

The landing mat and aiming point marking can only be implemented if a fitting sufficiently flush to be landed on and run over is available. Two fittings are available at present, one British, and one originally designed in Holland and now being developed in the U.S. The British fitting[7] (Fig. 12) is a small and highly refined design with a projection above the surface of the runway of only ¼ inch. This fitting has been installed in a runway for several years and although fittings have been

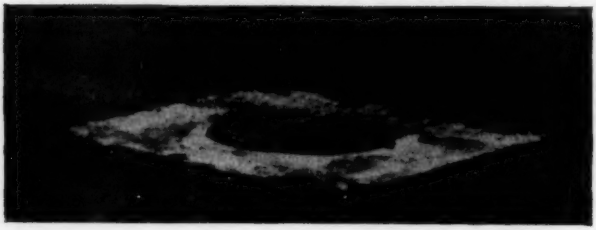


Fig. 12. British type flush runway light.

struck many times by aircraft no damage either to the fitting or the aircraft has been reported. As the function of the mat is to make the flare-out and landing easier and safer at night, high intensities are not required from this fitting; the beam must, however, extend right down almost to the horizontal and the horizontal spread must be wide, i.e., about 15 deg. or more assuming a toe-in of 2½ deg. If the spread were not wide, roll and height guidance would be lost when the aircraft touched down with a large lateral error and the whole purpose of the mat would be defeated. The Dutch design is completely buried in the runway and in order to meet the above requirements its size has to be enormous. The cost of installing the pattern shown in Fig. 6, using British fittings, has been carefully studied, and it is estimated that this will be about £5,000 for a new runway and about £6,500 for an existing one. With the Dutch fittings, and the pattern proposed in the U.S., the cost would probably be at least ten times as great with no corresponding advantage.

(15) Conclusion

Arguments have been put forward to show that guidance in the vertical plane needs to be improved if the present level of safety is to be maintained in the future, and ways of doing this visually have been described. The beam spread of the approach

lights should be increased and fittings for providing guidance in circling approaches should be developed. The British design of flush type runway light has proved satisfactory in actual operations, and as a result landing mats have now become practicable, even on existing runways.

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Discussion

CAPT. J. WOODMAN: As usual, listening to Mr. Calvert speaking on the subject of visual aids has been extremely stimulating. His knowledge of our problems is profound and, as a result of this, pilots the world over take a great interest in his work. I thank you, Mr. Chairman, for providing the opportunity of listening to him to-night.

The fundamental impression that comes to the fore from Mr. Calvert's paper is that although visual aids have been developed, as a result of his work, which satisfy the pilot's need for information of displacement and rate of change of displacement in the lateral plane, the same cannot be said for the vertical plane. As vertical errors are far more readily corrected than lateral errors this state of affairs might, at first thought, seem to be acceptable, but the trouble is that these errors can build up very quickly and, at times, reach dangerous proportions before detection.

Mr. Calvert mentioned that during the last five years, nearly all civil accidents which have been attributed to visual misjudgments, have occurred when the visual range was considerably above the minimum runway visual ranges quoted in his paper. Some of these accidents were attributed to vertical errors, errors in height assessment, which may seem surprising to you in view of the fact that the pilot is provided with a direct-reading height indicator—his altimeter.

I should like to take you quickly through the latter stages of an approach to give you my impression of why, once the pilot has made his transition from instrument flight to visual flight, he is reluctant to go back on to his instruments but prefers to fly visually, a more natural form of flight to him at low levels.

We will assume the aircraft is on the way down the I.L.S. approach path and the co-pilot indicates to the pilot that the approach lights are in sight. The pilot then begins to make his transition to visual flight. So far quite a reasonable operation. The pilot wishes to make his transition to visual flight as quickly as possible in view of the actions he must take before landing which will disturb the aircraft's steady progress down the approach path. During the transition to visual flight the pilot must decide whether to continue the approach to a landing or not, as well as commence to correct any displacement that is immediately apparent to him. Having decided to continue, he must destroy all the stability that has been so carefully engineered into the approach by changing the aircraft's configuration, i.e., applying full landing flap as well as by reducing the airspeed by some 20 m.p.h. before crossing the threshold. The pilot's

natural and understandable tendency is to continue flight using visual clues, more so because the configuration and speed changes have created discontinuity in the instruments indications that had been so carefully stabilised. It is during this stage of the approach that height judgment becomes quite critical and not at all easy. The relatively stable progress down the approach path has been rudely disrupted, the feel, trim and pitch angle of the aircraft have been changed, all at a time when visual height indications are far from perfect. Add rain, a windshield wiper banging to and fro, a squally cross wind, low visibility, a wet, slippery runway combined with inadequate means of determining the ground plane, and appreciate that from break out to touchdown is only about twenty seconds and you may understand why a pilot is concentrating hard outside to obtain the visual information that is natural to him at this stage of the approach, and not inside at his altimeter which can have large errors anyway. If these visual aids he is looking for are indequate, or what is even worse, become inadequate, these errors in height can assume proportions that become too large to be finally corrected.

I have taken you through the later stages of the approach in an attempt to give you some indication of why a pilot does rely on visual aids and why, even if aids tend to be not fully adequate to his needs, he is very reluctant to go on to instruments unless he has made a decision to go round again. If additional visual indications to improve ground plane definition and height judgment can be devised, they will play a significant part in increasing operational safety.

Visual aids to help the pilot should be developed as much as possible. There is no doubt that the angle of approach indicator which Mr. Calvert spoke to you about will go a long way towards meeting this need, but unfortunate that in really low visibilities it will not be truly effective. It is in low visibility that unequal spacing of cross bars may be misleading to the pilot in making height judgments.

The multiplicity of approach and runway lighting patterns, good and bad, that the average air line pilot encounters these days, tends to play havoc with his instinctive perspective judgment. More uniform patterns, in terms of both lateral and longitudinal spacing of basic elements should help. Uncompleted patterns, such as lines of lights without any cross bars, can be dangerously misleading.

The work that Mr. Calvert has done in developing the "standard visual pilot" theory is, as far as I am concerned, most important because it does stress the necessity for equating all the parameters involved in assessing visual aids, and I think that once the idea of this theory is grasped it will enable the users of visual aids to appreciate the scope and the limitations of such aids. Current endeavours effectively to measure slant visibility, one of the parameters involved, are praiseworthy, and I wish them every success.

As far as the landing mat is concerned, I think some form of landing mat is bound to come and that it will play its part in increasing operational safety, and I think that, as fully automatic approach couplers become consistently more dependable, the landing mat will play its part in maintaining economically satisfactory weather minima.

May I, as a practising air line pilot, take this opportunity of thanking Mr. Calvert for the tremendous amount of work he has done in developing and focusing attention upon the importance of visual aids to approach and landing, which must play an increasing role in maintaining acceptable levels of safety in actual operations in the future as aircraft get larger and their approach speeds increase.

GROUP CAPT. A. H. HUMPHREY: I would like to discuss for a moment the problem of transition from blind to visual conditions, because, in spite of the statistics which were quoted about accident rates on bad and good weather approaches, I think that this is the most difficult part of a landing approach.

Whilst watching approaches, both real and simulated, I have been impressed by

the increase in rate of descent which almost always occurs at this point. Sometimes it is very considerable and is all the more serious because, as the lecturer has pointed out, the vertical guidance provided by present-day lighting patterns is barely adequate if the aircraft maintains a stable approach, and is totally inadequate (above about 100 ft.) if the approach path is unstable.

This discontinuity in the approach path should not surprise us because, at the transition point, a pilot, who has been devoting his whole attention to instrument flying, must find and assess a lighting pattern :—

(a) which will be in a different plane of focus from his flight instruments,
(b) which may not be straight ahead of his aircraft,
(c) which has the runway threshold marked as a sort of datum, while the instrument approach system glide path will originate about 1,000 ft. up the runway,
(d) and which may be distorted by rain on the aircraft's windscreen.

Moreover, even when he had found and assessed the lighting pattern, the pilot must refer back to his flight instruments to make good the deficiencies in the vertical guidance provided by it.

In considering what can be done to smooth out this transition, it is really essential to examine the guidance and control of an aircraft throughout an approach and landing. Quite clearly, a great deal can be done by tightening up the stability of the non-visual control and guidance loop, and by extending its influence so that there is a relatively long period in which both visual and non-visual guidance is available.

However, for the purposes of this discussion I want to concentrate only on visual guidance, and there seem to me to be three basic requirements :—

(1) The vertical guidance must be greatly improved.
(2) There must be as little discontinuity as possible between visual and non-visual guidance.
(3) A pilot must be able to recognise and use the visual guidance pattern as soon as he sees it.

The measures which the lecturer has advocated go a long way towards meeting the first two of these requirements :—

(a) An angle of approach indicator to improve vertical guidance.
(b) An optical sighting device which could really give us rate information in the vertical plane. Could it also be tied in with the non-visual guidance system so that there was little or no discontinuity between the two ?
(c) A landing mat which will prevent the runway threshold appearing as the datum of the lighting pattern.

But can anything be done to enable a pilot to grasp the significance of a lighting pattern more quickly when he first sees it ?

Is it possible to get a greater degree of standardisation than at present ? It seems to me that standardisation on a good lighting pattern is far more important than independent attempts to achieve the perfect pattern.

Can we go further in our battle to eliminate extraneous lights ?

I often wonder whether obstruction lights do not in fact distract more than they help us, and I wonder whether we could not make an absolutely rigid rule that all airfield apron and street lighting should be screened so that it is not visible on the approach.

I am afraid I have little to say that is controversial, because I agree so strongly with almost everything Mr. Calvert has said in the past and said to-day. I would like to take this opportunity of thanking the President and the lecturer for giving me this opportunity to listen to his lecture.

MR. G. W. STALLIBRASS: It is not easy to comment usefully after a lecture with which one is in almost entire agreement. However, it is of interest that the need

for approach lighting is not yet universally accepted; in at least one country it is only considered necessary for instrument approaches on I.L.S. I think in this instance, however, the overriding factors are good weather and general use of a docile aircraft like the DC-3. The same considerations are unlikely to apply to aircraft with higher approach speeds and less manoeuvrability on approach.

As regards the Angle of Approach Indicator described by Mr. Calvert, a better name for it might be the "Safe Descent Path" Indicator. It has the advantage over the older tricolour instrument of giving more latitude in selecting and keeping to the approach sector and, when we flew on it at Farnborough last week, it appeared very promising indeed. After this the landing mat is probably the next step in helping transition from the approach lighting to the final flare out and touch down. It may not reduce weather minima but should make things much less difficult for the pilot. The figures of cost available to us are about three times those quoted by Mr. Calvert, but they are for each end of a runway whereas his may apply to one direction only.

I was glad to hear Mr. Calvert and subsequent speakers emphasise that there is a limit to the improvements that you can get from lighting. If safety is to be increased, and if weather minima are ever to be lowered appreciably, two other things will also be necessary. One is radio or radar navigational aids that will enable the pilot to stay on instruments to lower altitudes, and the other is the need for aircraft to have good low speed characteristics, including a good cockpit viewpoint. Without these the effect of lighting in poor visibility will be unnecessarily limited.

MR. A. M. A. MAJENDIE: I would like first to put one small matter right before making three comments. At the meeting seven years ago, Mr. Calvert showed certain aircraft instruments and pointed out the difficulties of controlling the aircraft by their means. You will be glad to know that we have made great strides in the design of such instruments since that date, and I would not like you to be misled, from Mr. Calvert showing you once again the same instruments, into thinking that no progress has been achieved.

Passing on to the use of automatic coupling on the approach, the first automatic pilot for commercial use, with an acceptable performance for this purpose, has just gone into service in this country, and I think that one of the most interesting outcomes has been the reaction of the human pilots. Their first reaction was to complain that the equipment brought them in on the approach far too high, and that they preferred to cross the runway threshold rather lower. The path followed by the automatic pilot is, of course, that defined by the I.L.S. Glide Path, which is so sighted as to give the best clearance from obstructions in the approach path. Clearly the human pilot should aim to follow a similar path when controlling the aeroplane visually, but has unfortunately got into the habit of aiming for the runway threshold. Perhaps the availability of the automatic pilot, to demonstrate to him what a correctly flown approach path should look like, will help to improve the accuracy of manually flown approaches.

The next point I would like to make is that I do not think that most people have realised how far control by visual guidance is assisted by the characteristics of the aircraft. If the latter has good positive stability it can materially help to assist the pilot in making visual judgments under difficult conditions, as he can hang on to a given condition for long enough to assess its effect over a significant duration of time. I do not believe that enough attention has so far been given to this aspect of the general problem.

The final point I would like to make concerns approach speeds. If you take a conventional aircraft with an approach speed of about 200 ft./sec., following a typical descent path of about 1 in 20, it will have a sinking speed of 10 ft./sec. Even at this speed the injection of a 1 deg. error on the descent path downwards, starting at a

height of about 200 ft., will lead to a serious undershoot of the runway, and this may not be noticed in the lower visibilities until the aircraft is below about 100 ft. In this condition the aircraft will have a sinking speed approaching 15 ft./sec., and a margin in the order of 5 seconds between recognising how low it is and hitting the ground. If the approach speeds are allowed to rise significantly, a very real dilemma arises as between preventing the sinking speed being too high, or allowing the approach path to become too flat. In the former case the time interval between recognising the undershoot and hitting the ground is very short; in the latter case a very small angular error in descent path can lead to a dangerous undershoot.

MR. H. A. STAFFORD: I have been very interested in this paper and there are just one or two comments I would like to make. I wonder if it is possible to get American figures of their accident rate in this country compared with their accident rate in the States. In this country the U.S.A.F. are flying on the standard R.A.F. pattern lighting; I think this comparison might be very interesting.

With regard to angle of approach indicators, there are two other types of approach indicators developed recently; one developed commercially for M.T.C.A. and which I understand is giving satisfaction; the other one I devised about a couple of years ago and I do not think it has yet been fully exploited. Much consideration is being put into improving angle of approach indicators.

The final point is in connection with these new blister (or flush type) lights. As I was originally responsible with Mr. Holmes for their design I am gratified to find that they are being found useful, but I am surprised at a beam spread of 15 deg. being called for; I think 7 deg. or 8 deg. would be enough. I wonder whether this wide beam spread is being influenced by the efforts made in the States with their high angle landing mat lights, where perhaps they think they want the beams wider when really the beams should be lower.

MR. J. G. HOLMES: When this paper was first being discussed with Mr. Calvert, he told me that the work on which he had to report included very little illuminating engineering, and although it might be of interest to those concerned with flying it would not be very interesting to illuminating engineers. I told him he was wrong, and his presentation has shown us that this paper is a study of the fundamental problem which faces us every time we switch on a light, namely the problem of presenting to the eye a picture which the mind can understand fully and quickly. This problem is more generally studied under the well-known phrase "the design of the visual field," and in this particular aspect of the problem Mr. Calvert seeks to design the pattern of light sources and the distribution of light intensity, so as to tell the pilot all he wants to know about the relationship of his aircraft to the landing area in a way that he can understand fully and quickly. In this sense I commend the paper to workers in every part of the field of illuminating engineering. Particularly, one would like to see this sort of analysis applied to lights on the road at night, and to have the problem of street lights and vehicle lights examined in this detached but positive manner.

The particular problem of aerodrome lights goes back as far as night flying, when flares and boundary lights and floodlights were used on grass airfields, and approach lights, threshold lights and runway lights were used on paved runways. As the problem has become clearer so the lights have changed, and the history of runway lights shows this very clearly. When they started in the 1930s they shone a beam vertically upwards, a direction in which it was never seen by a pilot. In 1938, W. M. Hampton calculated the beam should be at 45 deg. to 53 deg. elevation to give the pilot the best chance of seeing the runway lights in thick weather, but full allowance was not made for the fact that the pilot was not free to look sideways and downwards out of the cockpit during the latter stages of his approach to the runway, so that he would never have

been able to see a 45 deg. or 53 deg. beam. During the war a large number of runway contact lights were made giving a 100 candela beam at about 20 deg., and they worked fairly well under black-out conditions. In 1942, S. English developed a design giving a 1,000 candela beam at 7 deg. to 10 deg. elevation, and this was found to be very much more effective than the previous design. In 1948, S. G. Turner described a new design giving a 5,000 candela beam at about 5 deg., and again this was found to be an improvement in many circumstances, although it was necessary to dim the lights in clear weather. In 1955, the LR/21 fitting was developed by the speaker, and in the form described by Mr. Calvert in this paper it gave a 10,000 candela beam at about 3½ deg. elevation. This has more recently been developed into the LR/22 fitting, giving a 20,000 candela beam at 2½ deg. elevation. All these fittings consume something of the order of 50 to 100 watts, and of course the beam divergence has been reduced as the peak intensity was increased, to accommodate higher approach speeds with more accurate radio guidance on to the approach path.

The American practice differs from ours, and perhaps it suffers from the effects of full-scale trials without critical laboratory experiments, and from a persistent belief in the value of bigger and brighter lights. This has led to the use of elevated lights and intensities of the order of 50,000 to 100,000 candelas, which we have adopted in this country to some extent.

The present problem is to provide for faster aircraft and for landings in misty daytime conditions, and the logarithmic rate of increase of intensity involves a corresponding rate of increase in expense. It seems, however, very doubtful whether such high intensities are required, and Calvert has shown that we need a pattern of a larger number of smaller lights installed in the approach and landing areas, rather than the group of small searchlights to which our policy seems to have been attracted.

It seems that intensities need not be more than 10,000 candelas, but that the light must come from the right place and be accurately controlled in the right directions. Confusion can be caused by high intensity lights incorrectly placed and by excess of light in unwanted directions. Calvert's work has shown where to put the fittings in the approach runway areas and where to direct the beams, and it is reassuring to know that our current practice promises to be the best solution for this very critical problem of the relationship between speed and safety.

MR. A. G. PENNY: Mr. Calvert mentioned that the dangers at night are two and a half times as great as in the day, and implied that this increased hazard is associated with the difficulty experienced by the pilot in seeing as clearly the surface upon which he has to land. I should be interested to know whether a pilot is substantially assisted in his task by his ability, in daytime, to see the *detailed surface structure* of the runway. If it is a help for him to have a clear view of the surface of the runway, then ought we not to give some thought to the problem of lighting it at night?

The ordinary white concrete runway is, relatively speaking, an easy thing to see in daylight, but at night no attempt is made to help the pilot to see it. Indeed, the normal method of runway lighting has the effect of making the surface as invisible as possible, by surrounding it with a multiplicity of glaring light sources until the general appearance—to a lighting engineer—is that of a deep black hole of indefinite depth.

I have noticed that pilots usually land with the aircraft landing lights on, presumably in an endeavour to combat the glare from the runway lights and to reveal the surface, and should be interested to know whether in fact modern landing lights are of any real value, having regard to their necessarily limited power and the speed at which aircraft now approach the ground.

MR. L. F. E. COOMBS: What effect would snow and ice have on the British fitting? I note that there is a small depression in the casing which might trap snow or ice.

Powers used to exist relating to railway signalling where, I understand, the Ministry of Transport required lighting which interfered with signals to be masked. Is there a similar requirement relating to airfield lighting?

MR. J. W. SPARKE (contributed): I should like to comment on two points which have been raised in Mr. Calvert's paper and in the subsequent discussion. The first concerns the weakness of visual guidance in the vertical plan compared with guidance in the horizontal plane. The main reason why this is so is probably because, in the horizontal plane, the condition that the aircraft is tracking correctly over the extension of the runway centre-line can be recognised very easily by noticing, firstly, that perspective image is symmetrical about its centre-line, and, secondly, that the streamer velocities are symmetrical about this centre-line. In the vertical plane, the condition that the aircraft is following the nominal glide path is *not* associated with any symmetry in the perspective image or in the streamer pattern. The pilot, in order to obtain vertical information during a visual landing, must repeatedly estimate range from touch-down and mentally compare the picture he sees with the picture his previous experience tells him he ought to see from this position on the approach. With practice this becomes an almost continuous and subconscious process, but the guidance is never so precise as that available in the horizontal plane. The point to notice is that this is true in all visibilities, however good or bad.

The second point concerns the efficiency of the new R.A.E. Angle of Approach Indicator (or Safe Descent Path Indicator, as we now prefer to call it). In this indicator, the junction between the white and red sectors is not sharp. By experience, it is known that a reasonable angle over which the change-over from red to white must take place is about $\frac{1}{4}$ deg. It might be supposed, therefore, that since the distance between the slot and the filter is about 50 in., the slit width should be just under $\frac{1}{4}$ in. It will be found in practice that this is not so, and that an effective change in colour over $\frac{1}{4}$ deg. corresponds to a slit width of the order of 2 in.

This is due to the fact that as the observer moves across the colour junction, the rate of change of colour is not proportional to the amount of the slot width covered by the filter. For instance, in the middle of the theoretical change-over sector, where the filter covers half the slot width, the colour of the signal is still unmistakably white. Indeed, if the colour is calculated, it will be found to be within the specified limits for a white signal, as defined in B.S. 1376. This is very fortunate, because, with a 2-in.-wide slit, it is possible for about 50 per cent. of the light from each of the projectors to pass through it. Since the projectors themselves have an optional efficiency of the order of 50 per cent., the overall efficiency is about 25 per cent., i.e., twice the efficiency of the existing three-colour indicators which use the conventional magic lantern optical system. It is this high efficiency which largely explains the effectiveness of this indicator in daytime.

THE AUTHOR (in reply): I would like to thank Capt. Woodman for his remarks, particularly his description of how a bad-weather landing is made.

Capt. Woodman mentioned that an angle of approach indicator (AAI) is not effective in very bad visibilities, and that, of course, is true. Some idea of the limit of its usefulness can be obtained by considering the height at which the pilot will be able to see it, and comparing this with the probable height errors. If the slant range is one mile, the indicator will be visible when the aircraft is at a range corresponding to a height on glide path of about 260 ft. An undershoot should, therefore, be avoidable in this visibility unless the height error during the instrument portion of the approach is more than, say, 200 ft., and is combined with a high rate of descent.

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Since errors of this magnitude would be very infrequent, particularly with the new couplers, I think we might say that the indicator will be useful down to a slant range of one mile, and possibly a little below.

The point which I would like to emphasise is that there are theoretical and statistical reasons for thinking that the conditions in which accidents due to visual misjudgments are most likely to happen, at least in the future, are those in which the AAI will be effective. In the first place, operations are seldom conducted in slant ranges much lower than one mile unless the runway is equipped with a good approach lighting system, and if it is, the probability is that the runway is long. Incidentally, the cross-bar system has an excellent record for safety, and although I believe the safety margin is not very large, I think I am correct in saying that no civil aircraft has yet been involved in a serious accident of this kind on a runway on which this system is installed. Improved couplers, i.e., flight directors and automatic approach, are already coming into operational use, and with these the lateral errors are so small that it will normally be possible to postpone the point at which manual visual flight begins until a low height is reached, say, 200 ft. or even lower. At 150 ft. visual guidance in the vertical plane is reasonably good, and soon becomes better. Also, I understand that the probable procedure with these couplers will be that the pilot who is going to make the visual landing merely monitors the instrument portion of the approach, and does not take over until he feels he has a firm grip of the visual situation. When he does take over, the aircraft is normally on glide path and has the correct rate of descent, and his task in the vertical plane is then simply to hold this rate of descent until the flare-out begins. I think that all these, i.e., good visual aids, reliable and accurate couplers, and a good cockpit procedure, are necessary for regular operations in slant ranges of less than one mile, and where this combination exists, the danger is small down to a visual range of about 500 yards.

There are, however, many runways where, for reasons such as lack of money, small traffic volume, mountainous terrain, or proximity to the sea or to a town, it is not practicable to install a full approach-lighting system. For many years to come aircraft will be operating into these runways with G.C.A. or cross-pointer I.L.S., or even some less precise aid. In a great many cases the approach will be made visually, either because there is no electronic approach aid at all or because the weather is good enough to permit this. Typical limits for such conditions are a runway visual range of one mile and a critical height of 400 ft. I would like to give some reasons why I think the accident rate in these conditions may be higher than in the conditions described in the previous paragraph.

In the first place, G.C.A. and cross-pointer I.L.S. require mental computation on the part of the pilot, and he is less able to deal with any disturbing factor which may happen to crop up. This is very important if he is out of practice or suffering from fatigue. Secondly, he will normally have a substantial lateral error to correct when he goes visual and must therefore make the transition at a greater height. Correcting this error is in itself a difficult visual task on a defective ground pattern, and until it is finished, visual guidance in the vertical plane is virtually non-existent.

Thirdly, the sensitivity of the visual guidance in the vertical plane decreases as the height increases, and with high critical heights there is a danger of the aircraft acquiring too rapid a rate of descent at or after transition. All these reasons are important, but perhaps even more important is the fact that deficiencies in visual guidance in the vertical plane are greatly accentuated by such factors as the absence of the horizon, sudden variations in visual range, mountainous terrain, lack of texture, etc., all of which may exist when the visibility is quite high. Indeed, the visual range is not a very good measure of the difficulty of the pilots' task, particularly when the aircraft is fast and the runway is critical for length.

In support of this view, I would mention that in a recent investigation in the United States extending over two years during which 14,000,000 landings were examined, it was found that 95 per cent. of the combined overshoot and undershoot incidents occurred when the meteorological visibility was above three miles and the ceiling above 1,000 ft. Also, the accident rate was very much greater for approaches over the sea, over featureless terrain and for approaches at night. These are, of course, the conditions in which a good A.A.I. might be expected to be very effective.

It may well be that in the future there will be an even greater necessity for improving visual guidance in the vertical plane, because the easier the new couplers are to use, the more the present pilots will use them and the more their successors will be trained to use them. Both future and present pilots will therefore get less practice in visual approaches. Indeed, the chief pilot of one famous European airline told me recently that this was already a problem with the newer pilots, brought up, so to speak, on instruments. This problem will become more marked the larger the aircraft and the longer the stage length.

I strongly agree with Group-Capt. Humphrey that from now on the thing which will pay the largest dividends in safety is pattern standardisation. Unfortunately, the United States has adopted a civil standard for approach lighting which is different from most of the rest of the free world, and this pattern is such that the new A.A.I. cannot be used with it without modification to the pattern. I think, however, that the greatest obstacle in the way of international standardisation is the United States belief in the guidance and fog penetrating qualities of sequentially flashed lights. There are three ways of assessing the guidance provided by any system; firstly, subjective impressions based on actual flight tests; secondly, a statistical analysis of the approach success rate and the accident rate; and thirdly, a detailed demonstration of the psychophysical mechanism, which enables the pilot to obtain the particular elements of guidance which he needs to do this particular task. The first of these ways is untrustworthy, partly because the impressions are bound up with the stability of the aircraft, as Mr. Majendie says, partly because the test conditions are uncontrolled and partly because of the tendency to wish-fulfilment in human beings. So far, the case for sequence flashing rests entirely on subjective impressions. (Perhaps the believers fear that objective tests might show the need for an agonising reappraisal.) Since the closing down of the Landing Aids Experiment Station in 1950 there is no coherent and permanent body in the United States charged with doing systematic research into the theory and practice of the visual aids. Also, they are only just beginning to think seriously about visual landing simulators, and until they succeed in building one that is satisfactory, both theoretically and mechanically, they have no means of checking new ideas quickly under controlled conditions. The present situation of having different standards on the two sides of the Atlantic will therefore continue, and may even be extended to landing mats and A.A.I.s, in spite of efforts on both sides to prevent this.

I agree with Mr. Stallibrass that a better name for the type of A.A.I. described in the paper is "Safe Descent Path Indicator," and we propose to call it by this name in the future.

It may well turn out that the actual cost of the landing mat will be a little more than that given in the paper. All I can say is that that was the estimate given to me by the installation engineers after due consideration.

I agree with both Mr. Stallibrass and Mr. Majendie that once it is agreed that visual guidance in the vertical plane is not, and can never be, perfect, it follows that the descent track stability of the aircraft is of the utmost importance for safety. By this I mean the ability of the aircraft to continue along an established track if there is no force on the controls. It is because I think that the present safety margin is small that I am so anxious to ensure that the effects of increased approach speed and increased

time lag in response to control movements should be fully compensated for by improved aids.

I apologise to Mr. Majendie for showing you the cross-pointer meter on the blackboard and describing the difficulties of its use, but my object was simply to illustrate how the three guidance elements, displacement, rate and rate-rate, have to be combined, irrespective of whether the pilot is flying visually or on instruments. Since the correct combination can only be achieved by means of a continuous computation, either in the pilot's head or in a "black box," I strongly recommended the black box, firstly because, above a certain height, the raw data which can be fed into it is so much better than what can be fed into the pilot's head, and secondly, because it deals with both planes at the same time and not one after the other, as the human pilot tends to do. I would like to add that the particular black boxes for which Mr. Majendie has been so largely responsible seem to me to do the job in a very elegant manner.

With regard to increased approach speed, I think the dilemma posed by Mr. Majendie is very real. If a task is difficult and the margin of safety is small, then a small increase in the difficulty may produce a large increase in the accident rate. For instance, in the investigation mentioned above, the accident rate at landing due to "pilot error" was seven and a half times greater for jets than for propeller driven aircraft. I do not anticipate an increase of this order when the big civil jets are introduced, but in view of this experience and our own work on visual guidance, I feel that it would be wise to take every possible precaution. Instrument designers are aware of this situation, but I doubt if the aircraft designers are.

In reply to Mr. Stafford, a statistical analysis of approach success was made some years ago, both in this country and in the United States, and proved to be extremely useful. I have already mentioned the exhaustive analysis of accidents made recently in the United States. This has also been of the greatest interest to us, largely because it confirms many of our theories. I think that these statistical analyses should be continuous, and have already suggested this to some members of the group who are evaluating the experimental installations at Andrews Field, i.e., those who believe in sequentially flashed lights. As regards the horizontal beam spread, the Dutch-American fitting mentioned in Section 14 of the paper has a spread of about 5 deg., but the tests at Andrews Field have shown this to be insufficient and much larger spreads of the order of 20 deg. are now being tested. No amount of redesigning will remove the disadvantages of this fitting, because they follow from the fact that the beam comes out through tunnel and grille.

In reply to Mr. Holmes, I agree that the early runway and approach lights were often set far too high. The report of the sixth Session of the A.G.A. Division of I.C.A.O. has produced some useful information dealing with beam characteristics and settings, and this will be included in the Recommendations for International Standards, Recommended Practices and Procedures. According to this information, a typical well-designed approach lighting fitting might have a maximum intensity of 22,000 candelas, with a spread at 20,000 candelas of 10 deg. vertically by 30 deg. horizontally. As I drafted this item myself, I naturally agree with it.

Mr. Holmes suggests that the sort of analysis presented in this paper could be applied to lights on the road at night. I think one obvious application is the lighting of tunnels in daylight. Anyone who has driven at high speed into a dark tunnel with nothing but the exit circle visible in the distance, will remember the shock of suddenly losing the heading information necessary for holding a straight path and for manoeuvring. I think that the way to provide guidance in such conditions is not to try for greater and greater surface brightness, but to install a simple pattern of lights which will enable the driver to hold a desired path. I have in mind a longitudinal row of lights vertically over each traffic lane, with a few transverse rings and possibly a row down each side. I think Mr. Holmes referred to this problem in his paper on the lighting of London Airport. I might add that a pilot seeing the distant runway on a dark night, or through

a hole in the cloud, is in a very similar guidance situation to that of the motorist entering the tunnel, i.e., he has no streamer pattern.

In reply to Mr. Penny, experiments in the floodlighting of the runway have been made in this country and are at present being made in the United States. The trouble is that the fittings constitute an obstruction if they are higher than about 18 in. This means that the light strikes the surface at a very small angle, with the result that the observer sees the undulations in the surface as pools of light and darkness, and not the day markings and the actual texture of the surface as in daylight. Indeed, the appearance of the runway is rather as if snow had been blown across it, i.e., the apparent texture under floodlighting is artificial and spurious. Another difficulty is the enormous consumption of power as compared with a landing mat. Since the whole idea of floodlighting is to show up the real texture and the day markings, I hardly think that the results obtained justify the cost. On the other hand landing lamps carried by the aircraft *do* reveal both the real texture and the day markings and, in most weather conditions, seem to me to be better than floodlighting. Unfortunately landing lamps are dangerous in radiation fog, but so also may floodlighting be.

In reply to Mr. Coombs, the British fittings designed for use in the landing mat have been installed in a runway for about three years, and, as I have heard no complaints, I take it that they satisfy the weather conditions in this country. Whether any kind of flush type light, particularly one in which the light comes out through a tunnel and grille, would be suitable for a country in which there was much snow and ice is doubtful. All I can say is that the British fitting has been tested for snow-ploughing and found to be satisfactory from the mechanical point of view.

I am very pleased to have Mr. Sparke's contribution, because the two comments he makes are of the utmost importance. As the inventor, and almost sole maker, of the first satisfactory visual landing simulator, he has been largely responsible for the success of the work of my Section. He is also responsible for the design of the Safe Path of Descent Indicator. In his first comment he has put his finger on the essence of the difference in the quality of the guidance in the two planes, and it is largely because of this difference that the visual guidance *derived from a pattern* can never be good in the vertical plane, even when the weather is perfect. Hence the need for an indicator which is effective by day as well as by night.

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Changing Tastes in Design

By PAUL REILLY

In your presidential address last year, Mr. President, you laid down three unexceptionable principles by which the policy of this Society should be illuminated —namely, catholicity, authority, and responsibility. I imagine that I have been kindly invited here to-night under the first heading only, for I can speak with no authority on lighting, and I would not wish to be held responsible for anything I may say.

But under the umbrella of catholicity I may perhaps be allowed to discourse rather generally on the subject of design without sticking too closely to your last.

And since I was privileged to attend your very enjoyable annual dinner a few weeks ago at the Café Royal, during which I read the menu card with great attention, I may also perhaps be allowed to open my talk with a few quotations, all of which have, I hope, some bearing on the subject of design.

The first—from Confucius—I discovered in a most unlikely place, on the back of a door in a Sheffield factory. It appears that Confucius was once asked how he might recognise a good artist craftsman—or let us say to-day, a good designer. He replied: "First by the reputation of his ancestors for honesty and sincerity; second, by his ability to create something new with a tradition that is old." That, I believe, exactly describes both our past history and our present challenge in all aspects of industrial design, among which I would, for the sake of my argument to-night, include all the arts from architecture to handicrafts.

My second quotation is also of general application but also, I think, very relevant to our situation to-day. It is from the great speech that Prince Albert, the Prince Consort, made in 1850 at a Mansion House banquet to launch the Crystal Palace Exhibition in the following year. He was speaking, remember, in the context of the first great exhibition of industrial art. "I conceive it" he said, "to be the duty of every educated person closely to watch and to study the time in which he lives. Nobody will doubt for a moment that we are living at a period of most wonderful transition."

If that was true then, how much truer it is to-day, and how much more urgent the call for our architects and designers to keep their eyes on the times in which they are living—and yet who would guess that this is so from, for instance, the sort of Queen Anne palace that the National Farmers' Union have recently built for themselves in Knightsbridge or the more recently published impressions of the new headquarters for the English Electric Company to be built shortly on the old Gaiety site, or for that matter from the elevations of the new building for A.E.I. in Grosvenor Gardens. It would, I suppose, be unfair to refer to Magnet House in the same breath, for that was built before the prospects of a modern architecture had been properly opened up in this country.

Which leads me to my third quotation—one from a paper given in this very room just under a hundred years ago by the Victorian architect William Burges. He, too, was discussing current standards of design in industry and the impediments to progress, the principal one seeming to him to be "a want of distinctive architecture."

"Until the question of architectural style gets settled," he said, "it is utterly hopeless to think about any great improvement in modern art. It is most sincerely to be hoped that in course of time we may get something of our own of which we need not be ashamed. "This," he added, "may perhaps take place in the twentieth century; it certainly, as far as I can see, will not occur in the nineteenth"—a remarkable prophecy still on the way to fulfilment.

Industrial design, particularly in the lighting industry, is, I think you will agree,

The author is Deputy Director of The Council of Industrial Design. The manuscript of his lecture was received on May 4, 1957. The lecture was given at a meeting of the Society held in London on May 14, 1957.

almost inseparable from architecture. It is thus against a background of a divided architecture that we have to judge present standards—an architecture for one part modern and up to date, conscious of its own times and opportunities; for another part living in the past, in some make-believe world of period fancy-dress, however muddle-aged the period; and in between a vast area of opportunism littered with cynical hybrids with no convictions of their own—the City of London is unhappily sprouting examples at almost every corner. Who can therefore blame those industries that serve to complete and equip a building if they too appear design-wise rudderless and confused?

In a lively period of design all arts and crafts and industries move forward more or less in step. Our own eighteenth century was the perfect example of a consistent period; it would be hard to select from that century one art or craft as the pacemaker, other perhaps than the all-embracing art of architecture. In that century too, design was still developing, each generation adding to what had gone before and scarcely giving any thought to reproducing the successes of the immediately preceding centuries. There was little trade in antiques, as distinct from antiquities, and none at all in reproductions as we know them to-day.

It was thus in the three Golden Centuries, 1530 to 1830, that the real British tradition of design was founded, a tradition of experiment and development, not of copying and imitation. And it is because the products of those centuries won for themselves so high a reputation that those three hundred years have since become a sort of perpetual pie into which every Jack Horner in industry has blindly stuck in his thumb to pick out a plum.

It was of course, as Dr. Harper would I am sure agree, the industrial revolution that unhappily called a halt to the fine tradition of experiment and development; the tradition seems to have petered out towards the middle of the nineteenth century, with the result that many of the technical inventions of the Victorians reached the market aping something that had gone before. Gas and electricity both in their turn suffered from this kind of retrospection.

I need not I think spend much time on recalling the causes of debasement in so many of our consumer industries; the decline of craftsmanship, the divorce between the designer and the manufacturer, the loss of contact between the manufacturer and his customers, the peopling of the gap by a host of middlemen with no first hand knowledge of what they were handling, have all been described fully and expertly and often, and so too have the many endeavours to raise standards starting with what has been called "the intellectual Ludditism" of Ruskin and Morris, through the work of the Arts and Crafts movement to the founding of the Design and Industries Association in 1915 and the setting up of the Council of Industrial Design in 1945. But all these endeavours, however admirable in themselves, speak of failure to maintain standards in British industry.

Yet there is one cause of this declension that has perhaps not been emphasised enough. I refer to the Victorian idea, still current to-day in many quarters, that art was something to be bought in the market place and applied to industry.

The word "art" has never been so overworked to so little purpose as in the middle years of the last century. Art-manufactures, art-bronzes, art-furniture, art-foliage, artistic-conservatories, even artistic sanitary fittings—the word could sell anything as long as it cost enough. By contrast our own current favourites, such as "good design" and "simple form," seem to have been reserved in the catalogues for the cheaper lines only—which really marks the great divide between the old idea of applied art and the new conception of industrial design.

Mathew Digby Wyatt, a Victorian critic of the exhibits in the 1851 Crystal Palace, half put his finger on this point when he complained that so many British manufacturers "borrow ornaments expressive of lofty associations and apply them to mean objects."

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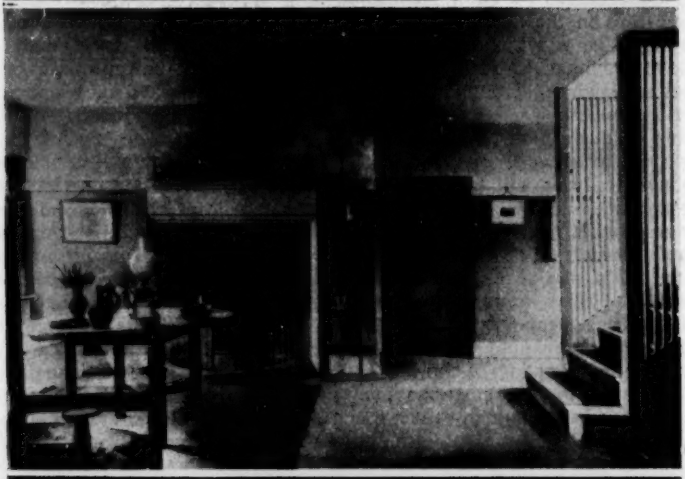

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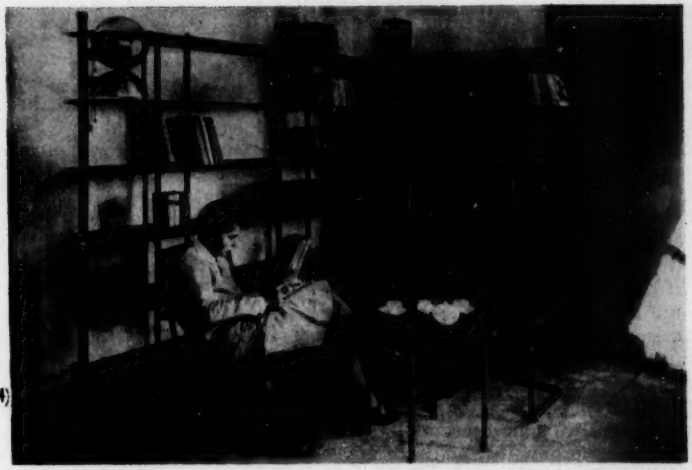


(5)

The recurring rhythm of taste from the rich to the simple, from the simple to the elegant, and from the elegant to the rich again. (1) A late Victorian sitting-room, full blown and cluttered; (2) a room of the same date showing already the swing of the pendulum; (3) still simpler and more "Doric," an architect's home in the nineteen-thirties; (4) the protest carried to extremes—a cosy corner in a Continental modern home of the same period; (5) the pendulum swings again—a post-war modern room, showing a return to warmth and comfort, in no way imitating the past and not yet as elaborate as the first room. In many people's estimation the middle phase of the cycle is likely to be the most satisfactory; the other two are always prone to exaggeration.

XUM

He was, in short, criticising the element of pretentiousness that so quickly cheapens a product and so surely renders it commonplace, but he was also getting near to Sir Herbert Read's analysis of the malady. In his famous book on Art and Industry, Sir Herbert condemns the Victorian tradition of connoisseurship or dilettantism which is summed up in the expression Good Taste. To it, he says, we owe the great confusion of values by which applied art has come to be mistaken for design.

This confusion has been apparent in many industries, your own not excepted, with the result that forms or patterns are imposed on a product for historical, conventional or social reasons with little regard either to methods of fabrication or to function.

It was not until the modern movement in architecture got under way in the early years of the twentieth century that industrial design, as we think of it to-day, was liberated from these preconceived notions.

But the modern movement, being in part a protest against late Victorian opulent ornament, started by wiping the slate almost too clean. The first phase of modern architecture was square, spare and bare, severely puritanical and rigidly functional. The Design and Industries Association launched its first campaign in 1915 under the banner of fitness for purpose. It was thought that all that was required was for form to follow function to achieve beauty—a half-truth that we have since grown out of, without, I hope, returning to the idea of applied art, or ornament for ornament's sake.

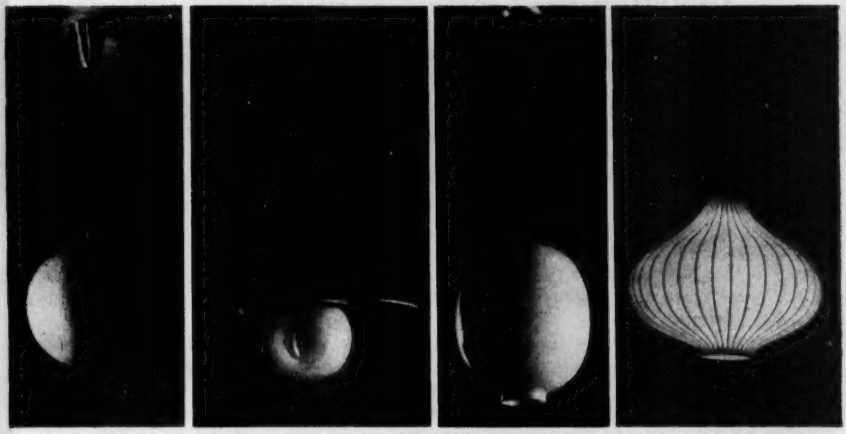
Sir Herbert Read gives some more good advice on this point when he qualifies his bald statement that " all ornament should be treated as suspect " with the concession that the only real justification for ornament is that it should in some way emphasise form.

Your industry has in this century kept in step with these developments in modern architecture, or rather only those members of it who have tried to follow Prince Albert's advice about studying the times in which we live. The frosted footballs of the 1930s exactly expressed the then fashionable elimination of all emotion, with the result that there was at that time no halfway house, so to speak, between the functional or clinical and the lush suburban, between the bathroom wall strip and the parchment-shaded electric candles or between the office desk light and the overhatted vase. The ordinary person found modern lighting acceptable only for the working parts of the home, for the kitchen or bathroom, but clung to the older conventions for the living-rooms.

There was thus a wide and unbridgeable gap between the ideas of the creative few, the modern designers and architects, and the instincts of the many. Few large firms would risk any great investment in modern design since the market was so restricted. The more credit therefore to those few pioneer firms—they must, I suppose, be nameless on this occasion—who stuck to their guns and eventually won through.

Why have they won through? Why is contemporary lighting now so popular and so widely acceptable in all parts of the house? I think the answer can be found in what might at a stretch be called a natural law, a sort of recurring rhythm of taste which history has revealed in many periods and many styles of architecture. I have sometimes likened these cycles to the three stages in nature—the budding, the blooming and the fall. Or one can take an architectural analogy and describe the stages as Doric, Ionic and Corinthian. At all events many architectural styles have started simply, have matured decoratively and have ended richly.

The modern movement does not look like being an exception. The Festival of Britain marked the turning point in this country from the first to the second phase. Even the grammar of criticism has pointed the change. Early modern buildings would be described by their friendliest critics as bold, plain simple or functional—all Doric words. Present-day modern buildings are more likely to attract adjectives such as light, elegant, graceful or colourful—even the



The same development from functional simplicity to greater interest in line, texture and colour can be seen in these four light fittings: (1) from the late 1920s, (2) from the '30s, (3) from the '40s, and (4) from the '50s.

word pretty is no longer taboo. And this applies throughout the field of contemporary design from architecture, through furniture, to pottery, glass and light fittings.

To a great extent this maturing process has taken the sting or commercial risk out of modern design, since the mellowing of the tastes of modern designers has gone far towards bridging the gap between their ideas and the conventional tastes of the public. Adolf Loos, the Austrian architect, one of the early pioneers of modern design on the Continent, once declared that the lower the standards of a people the more lavish are their ornaments—he was speaking of educational standards of course.

So, as I see it in moments of optimism, we may one day arrive at a stage in which public demand has through education been purged of its baser excesses and our designers purged of their own opposite ones, and all will be satisfied. There will be far less incentive to perpetuate Adam sconces and electrified wicks and wax, once the fun has been put back into function.

But liberation from preconceived notions brings its own risks and pitfalls. In the wrong hands so-called contemporary design can be just as unpleasant as so-called traditional. The furniture industry to-day shows many examples of this and so does your own industry, particularly in domestic lighting. Before writing this, I went along to the lighting department of a London store that is well known for its modern furnishings, just to check my impressions, and honestly it was like being in a parrot house struck by a rainbow—so many conflicting colours, so many over-contemporistical shapes, in sum so noisy and fidgety that only St. Vitus could have felt at home there.

The trouble is that things are moving almost too fast to-day. Too many of our old-established, staid domestic industries have been jerked out of their accustomed rhythm and suddenly find themselves turned into fashion industries. Novelty has become equated with contemporary and contemporary with commercial to such an extent that the responsible manufacturer must often ask himself where it is all leading, and the modern-minded critic must frankly admit that, in furniture, fabrics and even light fittings, " repro-contempo " has become as great a menace as " repro-jaco."

We are of course only paying the penalty for the long years of sloth and lethargy

when British industry invested nothing in design research but idly allowed its draughtsmen-designers to go on reproducing with minor variations the old stock lines that had proved successful for so many decades. The result was that when demand changed there was nothing in the pipeline to meet it.

Only by continued research and experiment by properly qualified designers with a strong sense of the architectural times in which they are living, and in your industry a proper grounding in engineering, can we hope to get back on to an even keel and perhaps slow down the wheels of fashion. With the ball at their feet and the rainbow at their beck and call, modern designers and their employers must beware these pitfalls of ephemeral fashion. If they do not take care a revulsion may set in against all expressions of twentieth-century design, and the misled public may once again be forced to take refuge in the past. And that, I think, would be a very sad outcome to all the good ideas and original thinking that have produced a revolution in design in our own lifetime.

That is why—if I may be allowed to plead the cause of my own organisation—a permanent *selective* exhibition like the Council of Industrial Design's Design Centre offers such a useful and necessary corrective service to-day. In many industries to-day it is not so much a question of selecting the modern as opposed to the reproduction, as selecting the good and the genuine from the second-rate meretricious imitation.

I feel I can say these things quite bluntly before an audience such as this, since you are for the most part engineers, and engineers almost by definition should be more prone than others to reject the facile and the frivolous and to stick to common-sensical solutions.

Summaries of Papers Published in the Transactions, 1948-1957 (Vols. 13-22)

Part I: The eye, vision and visual problems.
Part II: Photometry and colorimetry.
Part III: Lighting principles.
Part IV: Lighting practice and applications.
Part V: Research and development.

Part 1: The Eye, Vision and Visual Problems

(Glare; flicker; colour vision; visual fatigue; visual landing aids; visual performance.)

Fundamentals in Visual Aids for Aviation Approach and Landing
E. S. CALVERT
22 (10), 271, 1957

Brings up to date the theory of visual landing aids previously described in the author's 1950 paper to the Society, and discusses various practical methods of increasing the safety of the approach and landing operation. Indicates the need for improvements of the guidance in the vertical plane, and in the beam spread of approach lights, and for the development of fittings to provide guidance for circling approaches. Mention is made of the success of the British type of flush runway light which has enabled landing mats to become practicable.

Visibility on the Road
A. J. HARRIS
22 (9), 243, 1957

Discusses existing methods of measuring visibility in a road lighting installation and analyses the underlying concepts to emphasise the difficulties involved. Examines the various possibilities for expressing the performance of an installation by a single number on a scale based on visibility and concludes that this is not possible, but that a comparison between installations can be made in terms of safety. The practical difficulties in accomplishing this are discussed and the direction future work should take to this end is indicated.

Relative Brightness of Coloured Light Sources
H. M. FERGUSON and W. R. STEVENS
21 (9), 227, 1956

Describes laboratory and field investigations which showed that at high luminances mercury light sources appear brighter than sodium of equal photometric luminance. The field results were less marked than those conducted in the laboratory. Concludes that the common preference for sodium street lighting is partly explained by this effect, but is chiefly attributable to the characteristics of lanterns in current use.

Eyestrain in Cinemas, Report of the Committee on (W)
21 (7), 168, 1956

Dark Adaptation and Miners' Nystagmus
W. J. WELLWOOD FERGUSON (W)
21 (2), 42, 1956

Reports on continuation of work on this subject referred to in a previous paper by the author.

(W) Indicates written contribution.

Reflected Glare, a Preliminary Study of
P. PETHERBRIDGE and R. G. HOPKINSON (W)
20 (8), 225, 1955

Gives preliminary results of a study of the factors giving rise to reflected glare, which demonstrate that its chief manifestation is the distraction caused, rather than discomfort or disability.

Colour Preferences in Television Pictures, a Preliminary Survey of
M. GILBERT (W)
19 (8), 225, 1954

Describes an investigation which shows that the colours of a reproduced scene need to be less saturated than those of the original to satisfy the general viewer, and that the reproduced scene might also be preferred a little bluer than the original.

Glare, Two Supplementary Studies on
R. G. HOPKINSON and P. PETHERBRIDGE (W)
19 (7), 220, 1954

Describes an investigation which shows that the results of glare study using model-scale installations may be applied to full-scale installations, and that these results will satisfy about 85 per cent. of the general population.

Flicker Discomfort in Relation to the Lighting of Buildings
J. B. COLLINS and R. G. HOPKINSON
19 (5), 135, 1954

Describes experimental investigation of flicker discomfort, mainly with the whole viewing field fluctuating in luminance.

Shows that in good installations the problem is not serious. It is more serious with large areas of low luminance than with small ones of high luminance. Most probable cause is (50 ∽ supply) 50 ∽ flicker-component superimposed on normal 100 ∽ wave-form.

Visual Fatigue, with Special Reference to Lighting
H. C. WESTON
18 (2), 39, 1953

Discusses the application of the common notion of fatigue to the visual organism, and considers under what lighting conditions "visual fatigue" is most likely to occur. Concludes that visual fatigue may be defined in terms of the ordinary conception of fatigue as weariness resulting from bodily and mental effort; sub-optimal lighting conditions accelerate the onset of this condition.

The Eye, Brightness and Illuminating Engineering
W. S. STILES
17 (9), 241, 1952

Reviews the basic facts concerning the quantity brightness and its rôle in vision, and examines its suitability as a basis for lighting specifications. Concludes that despite the fund of knowledge on the retinal response to light it is difficult to deduce guidance for the use of the lighting engineer. This is often best obtained from *ad hoc* studies.

Dark Adaptation with Special Reference to Miners' Nystagmus
W. J. WELLWOOD FERGUSON
17 (3), 49, 1952

Describes the process of dark adaptation and tests made on subjects Suggests that the primary cause of miners' nystagmus is low luminance at the coal-face.

Brightness Patterns and Visual Fields
S. D. LAY (W)
16 (7), 172, 1951

Examines brightness patterns and their effect on visual efficiency in the light of research and current practice. Analyses two fields, one centred on the work and one covering the environment. Proposes standardisation of the zones into which the visual field is divided for research and the application of its results.

The Revealing Power of Street Lighting Installations and its Calculation
A. J. HARRIS and A. W. CHRISTIE (W)
16 (5), 120, 1951

An extension of the work of Waldram and others in this field. Shows that revealing power values, approximating closely to the true values, can be calculated from mean pedestrian illumination and road luminance. Curves are given showing the approximate revealing power as a function of these two quantities. Shows how the curves may be used to find revealing power and the broad effect of changes in the lighting.

Visual Aids for Landing in Bad Visibility with Particular Reference to the Transition from Instrument to Visual Flight
E. S. CALVERT
15 (6), 183, 1950

Describes some of the illusions occurring at transition and shows how they can be largely prevented by a Crossbar System of Approach Lighting. A brief account of the results obtained operationally are given. Describes a new "parafoveal streamer" theory of visual judgment from which desirable characteristics of visual aids are deduced.

Discomfort Glare and the Lighting of Buildings
P. PETHERBRIDGE and R. G. HOPKINSON
15 (2), 39, 1950

Describes an investigation to obtain more detailed knowledge of the effects of glaring light sources on comfortable vision, using a subjective appraisal technique. Shows that discomfort glare depends on the relation between the brightnesses of the glaring source and of the surroundings. Discusses application to design problems, methods of reducing glare and gives formulae and calculations.

Visual Performance, Age and Illumination in Relation to
H. C. WESTON (W)
14 (9), 281, 1949

Analyses the performances recorded for tasks visually comparable to "close work" by a group of male subjects aged between 19-47 years at illuminations varying from 0.5 to 512 lm/ft^2. Shows that performance declines with age whatever the illumination. The effect of varying illumination increases with age and as detail size and contrast are reduced.

Lighting and Vision in Schools, Studies of
R. G. HOPKINSON (W)
14 (8), 244, 1949

Describes a four-stage investigation into the problems of school lighting and vision associated chiefly with teaching from fixed chalkboards. Includes auxiliary studies of the effect of illumination and contrast on acuity and ease and speed of reading and of the factors which influence glare.

Part II: Photometry and Colorimetry

(Spectrophotometry; standards; physical measurement; instruments; photometric properties of materials; sources.)

Fluorescent Lamps, Measurement of Electrical Characteristics of
W. R. BLEVIN
22 (6), 164, 1957

Discusses the effects on electrical and photometric characteristics of fluorescent lamps of connecting electrical measuring instruments into the circuit. Reviews briefly the shortcomings of conventional instruments, and methods of overcoming them. Describes a new method, using conventional instruments, by which accurate corrections can be simply made for the presence of the instruments in the circuit.

Photometry and Colorimetry, Recent Developments in
G. T. WINCH
21 (5), 91, 1956

Describes new tungsten filament secondary standards, and tubular fluorescent secondary standards which showed good agreement in measurements when used in an international photometric and colorimetric intercomparison. The effect of new C.I.E. observer data on photometric and colorimetric values is indicated. Describes new physical methods, including photon counting for higher sensitivity. Describes new improved integrator paint. Refers to colour rendering of sources in relation to subjective effects and objective measurements, and to possible applications of ultrasonic modulation to colorimetry.

Transmission Measurements on Opal Materials
P. H. COLLINS and W. E. HARPER (W)
20 (3), 109, 1955

Discusses factors affecting transmission measurement on diffusing materials, and describes apparatus for laboratory use and factory process control of diffusing properties of opal diffusing materials.

Tungsten Lamps for Use as Photometric Standards, the Seasoning of
W. R. BLEVIN, W. J. BROWN and K. S. SARMA (W)
20 (3), 99, 1955

Describes measurements which show that recrystallisation of the tungsten filament is the main process involved in seasoning. A decrease in filament emissivity, largely independent of wave-length, during seasoning is indicated. Seasoning at lower colour temperatures is advantageous for operation at higher colour temperatures.

Diffusing Materials, Classification of
Report by J. G. HOLMES for B.S.I. sub-committee on Diffusing Materials acting for the N.I.C. (W)
18 (8), 221, 1953

Spectral Distribution of Radiation from Sun and Sky
J. N. HULL (W)
19 (1), 21, 1954

Analyses results obtained by apparatus described in following paper.

Spectrophotometry of Radiation from Sun and Sky
E. R. COOPER and M. C. PROBINE (W)

19 (1), 8, 1954

Describes spectrophotometer and associated equipment for measuring the spectral distribution from sun and sky or sky alone.

The Non-Additivity of Heterochromatic Brightnesses
A. DRESLER (W)
18 (6), 141, 1953

Reviews three independent investigations showing a definite non-linear relationship between apparent brightness and C.I.E. luminance of differently coloured surfaces. Discusses the trend of the relationship, and suggests ways of assessing heterochromatic brightnesses in terms of their luminances.

An Illumination Laboratory, the Equipment and Functions of
H. F. STEPHENSON
17 (1), 1, 1952

Reviews typical problems arising in an illumination laboratory and apparatus and techniques used to solve them.

Projected Light, the Photometry of
J. M. WALDRAM (W)
16 (8), 187, 1951

Discusses the problem of measurement of the performance of projection equipment such as that used for signals, beacons and searchlights and methods and equipment used for various classes of projector in laboratories in different countries.

Part III: Lighting Principles

(Theoretical; calculations; design; training; analytical; reviews; manufacturing methods.)

Automobile Headlamps: The I.S.O.-C.I.E. International Tests and their Influence on Meeting Beam Design
J. H. NELSON
22 (6), 141, 1957

Describes the background against which the international tests organised jointly by the International Standards Organisation and the Commission Internationale de l'Eclairage were carried out. The recommendations of the joint working party set up by these two organisations are discussed, and the adoption is noted of an asymmetric beam, hitherto the distinguishing characteristic of Anglo-American practice, as the new unified European beam.

Artificial Lighting as an Effective Aid to Architecture
H. E. BELLCHAMBERS, R. V. MILLS and H. R. RUFF
22 (7), 181, 1957

Describes methods by which the lighting engineer can plan the artificial lighting of a new building so as to suit the purpose of the building and satisfy the architect's conception of its internal appearance by artificial light. Following a discussion of the features of available light sources and of types of luminaire, the problems involved are considered in some detail and are illustrated by reference to a simple example, the lighting of an entrance hall. The use of scale models is advocated for checking illumination and luminance values and for obtaining a subjective appraisal of a design.

The Starting of Fluorescent Lamps
D. T. WAIGH and L. C. WILTSHIRE
22 (5), 115, 1957

Distinguishes three classes of method for starting hot cathode fluorescent lamps. Deals with processes involved, and discusses the factors affecting ease of starting by means typical of the three basic methods, and the choice of starting method with reference to the limitations of the more common types.

A Method of Calculating Flux from an Isocandle Diagram Using a System of Discrete Points
DOREEN SMITH (W)
22 (4), 105, 1957

Shows how to calculate the flux represented on part or on the whole of an isocandle diagram by reading the intensity at suitably chosen points and applying a simple formula. The arrangement of the points is chosen to suit the calculation to be made.

A Method of Evaluating Seeing Distances on a Curved Road and its Application to Headlight Beams in Current Use
V. J. JEHU (W)
22 (3), 69, 1957

Describes a method for evaluating seeing distances when two vehicles meet on a curved road at night. The method is a development of that used for straight roads. It is applied to three systems in current use, and the systems are compared. The modern double-lamp and the earlier single-lamp British systems are also compared.

Lighting Developments in Czechoslovakia
JIRI HAVELKA
22 (2), 35, 1957

Describes researches into economics of lighting in Czechoslovakia in recent years particularly as regards economical voltage of filament lamps and maintenance routine, and most favourable arrangements of fluorescent lamps.

Lighting Equipment and its Maintenance, a Critical Analysis of
J. MORTIMER HAWKINS and C. J. VENESS
21 (10), 277, 1956

Draws attention to advantages and difficulties arising from the design and construction of lighting equipment. Gives typical examples of economical maintenance in factories, offices and stores, and discusses experience of various light sources in relation to maintenance.

Light and Colour in Daily Life
J. W. STRANGE and H. HEWITT
21 (10), 255, 1956

Reviews current lighting conditions and points a need for greater diversity in lighting levels, brightness, direction and colour. Proposes practical studies on these lines, and suggests that lessons might be learnt from theatre practice. Comments are made on the economics of lighting, and an examination of the reaction of the public to a wider choice of light sources now available.

Symposium on Screen Viewing (3 papers)
21 (8), 199, 1956

(1) The Viewing of Cinema Screens
LESLIE KNOPP

Discusses factors involved in viewing screens in commercial cinemas where screens are of the reflective type and light sources are carbon arcs.

(2) The Viewing of Television Screens
R. D. NIXON

Discusses factors involved in viewing television screen pictures. Describes experiments in viewing with illuminated surrounds to the picture.

(3) The Viewing of Radar Screens
S. T. HENDERSON

Describes a lighting system which provides good near-white ambient light without detracting from the visibility in the radar-screen presentation.

Some Polarised Headlight Systems
V. J. JEHU (W)
21 (7), 160, 1956

Discusses American and German proposals for the use of polarised headlights. Mentions driver-appreciation tests and experiments suggesting ways of overcoming objections raised to the systems as proposed.

Polarised Headlight Filters
V. J. JEHU (W)
21 (7), 149, 1956

Discusses the relative merits of commercially available filters for the purpose of reducing handlamp glare by using a polarised headlight system. Compares performances of such a system and of the ordinary system. Mentions drawbacks to a polarised system.

Decorative Lighting—A Designer's Approach
D. W. DURRANT
21 (6), 117, 1956

Deals broadly with aesthetic aspect of lighting. Reviews the trend of design, referring to factors such as colour, form, light and shade, contrast and novelty.

Direct Flux, Inter-reflections and Final Luminances in Rectangular Rooms
R. O. PHILLIPS (W)
21 (4), 75, 1956

Develops a method for finding the average illumination on any surface of a rectangular room from the other surfaces, using Hisano and Yamauti principles. Gives examples.

Lighting in Buildings—Training and Practice
DEREK PHILLIPS
21 (3), 49, 1956

Examines the training and practice of the architect and lighting engineer to identify the weaknesses of present systems. Suggests methods of improving the knowledge of each class of expert of the other's subject and outlook.

Surface Distribution Factors and the Inter-reflection Method
RONALD CROFT (W)
20 (9), 259, 1955

Develops a method of lighting design based on a simple analysis of the polar diagram. "Surface distribution factors" related to flux distribution are derived and given graphically for an extended range of standard distributions. Useful appendixes include performance data for a wide variety of luminaires.

Lighting Design and Brightness Patterns—a Preliminary Investigation

H. E. BELLCHAMBERS and K. R. ACKERMAN (W)
20 (2), 79, 1955

Describes an investigation to devise a lighting design method in which the lighting arrangement is derived from a consideration of the illumination and brightness patterns required. The various factors to be considered in installation design are combined in a proposed new design method taking account of all the brightness patterns involved.

Vehicles Meeting on a Straight Road, a Comparison of some Headlight Beams for

V. J. JEHU (W)
20 (2), 69, 1955

Applies a method of evaluating direct seeing distances, when two vehicles meet on a straight road, to two common headlight systems, one representing British and American and the other European practice. Various aspects of beam performance in the two systems are compared. Compares also the British double-lamp system with a system in which the meeting beam comes only from a single lamp, on the near side, of the same intensity in the forward horizontal direction as that from the two lamps.

Vehicle Meeting Beams, a Method of Evaluating Seeing Distance on a Straight Road for

V. J. JEHU (W)
20 (2), 57, 1955

Describes a method of calculating distances for seeing objects in driver's own headlight beams when two vehicles meet on a straight road. It is based on experimental data which are extended by means of the Stiles-Halladay law to other straight road conditions. Experimental checks given.

Decorative Approach to Commercial Lighting

ANDRÉ CLAUDE
19 (10), 341, 1954

Discusses decorative problems introduced by fluorescent lamps. Considers the artistic basis of decorative lighting. Recommends methods of application of fluorescent and incandescent lighting for decorative purposes.

An Empirical Formula for the Computation of the Indirect Component of Daylight Factor

R. G. HOPKINSON, J. LONGMORE and P. PETHERBRIDGE (W)
19 (7), 201, 1954

A formula is developed from treatment of the inter-reflections in rooms on the basis of integrating sphere theory. Light received directly from the sky is treated separately from that reflected from the ground. The formula lends itself to simple forms of calculation and gives results approximating to measured values.

Flame-proof Lighting Equipment, Design and Application of

D. A. STRACHAN
19 (6), 169, 1954

Deals chiefly with mechanical design features of luminaires for use in hazardous situations.

Interior Lighting, Studies in
J. M. WALDRAM
19 (4), 95, 1954

Describes studies on adaptation, revealing of form and texture, and emphasis as three aspects of interior lighting. Proposes use of "Apparent Brightness" and adaptation in lighting calculations. Outlines a new method for determining effects of inter-reflection. Describes apparatus for the study of modelling and shadow and gives results for some interiors. Techniques of the experimental study of complete interiors are described.

"Reflected Component" in Daylighting Design
A. DRESLER (W)
19 (2), 50, 1954

Reviews attempts to treat the problem of reflected light in daylighting design by mathematical and empirical means. Emphasises the importance and difficulty of presenting results simply. Mentions the method of Biesele, Arner and Conover as being promising in this respect.

Vehicle Headlights, a Survey of
V. J. JEHU (W)
18 (9), 249, 1953.

Results are given of a 1952 survey of the condition of vehicle headlights as regards alignment and intensity. Their bearing on dazzle is discussed.

Reflector Contour for use with Tubular Light Sources
R. W. STEVENS (W)
18 (9), 243, 1953

Describes design of reflectors alternative to the parabola to avoid loss of light above the horizontal. Application to practical systems is discussed.

Visual Field, the Design of the,
Report by Sub-Committee on the Principles of Lighting for the N.I.C. (W)
18 (8), 225, 1953

Part I deals with the aims of good lighting; Part II discusses visual phenomena associated with seeing in interiors; Part III discusses the formation and methods of determining the brightness pattern. Bibliography.

The Meeting Beams of Headlights, Effects of Deterioration and Mis-aim
A. J. HARRIS (W)
18 (8), 207, 1953.

Discusses the effects of mis-aim on the effectiveness of well-designed beam distributions as regards seeing and freedom from glare when vehicle headlight beams meet. Gives data enabling sharpness of cut-off to be found for various degrees of freedom from dazzle.

Office Lighting. Discussion on Post-war Building Studies No. 30. The Lighting of Office Buildings
Introduced by P. V. BURNETT
18 (6), 166, 1953.

Colour in Schools
D. MEDD
18 (5), 123, 1953

Examines Ministry of Education Building Bulletin No. 9 on Colour in Schools. Discusses the functions of the architect and lighting engineer in this field, and the importance of colour.

Colour-rendering Properties of Fluorescent Lamps and a Proposed New Method of Specification
S. T. HENDERSON and D. T. WAIGH
18 (4), 113, 1953

Discusses "Band" systems for assessing the colour-rendering properties of light sources, and suggests a new criterion, the "Red-rendering Index" based on relative energy at two selected wave-lengths as compared with the ratio for a black body of similar colour. Methods of measurement, and data for wide range of lamps are given.

Interior Lighting Equipment, The Design of
L. H. HUBBLE
17 (10), 313, 1952

Records major developments in interior lighting equipment and indicates the probable lines of future progress. Discusses some problems in the design of standard fluorescent fittings and analyses briefly the units required for some special installations. Makes a plea for rationalising lamp and component design to assist fitting makers in reducing some of the variables in their equipment.

Lighting in the Design of Schools
A. POTT
17 (10), 293, 1952

Discusses the effect of changing ideas in education, teaching methods and building techniques on school design and use. Appreciation of the importance of scale and character, and newer teaching methods are demanding multi-purpose rooms. Discusses the provision of suitable artificial and natural lighting for the new schools, and critically reviews some recent examples.

Lighting Art, Two Frontiers of the
H. L. LOGAN
17 (9), 265, 1952

Deals with recent American progress in the solution of two "frontiers" or "unsolved problems" of lighting: (1) Desirable or permissible brightness patterns within the visual field, (2) Development of a technique for pre-determining the light conditions leading to visual comfort.

Comfortable Lighting—Its Study and Realisation
L. C. KALFF
17 (8), 227, 1952

Analyses the arrangements of line, colour and brightness components of a scene in the various parts of the visual field in relation to the nature and purpose of the objects of regard and surroundings and the effects on visual comfort.

Lighthouse Lens, the Control of Light by
W. M. HAMPTON
17 (3), 63, 1952

Gives a brief historical survey, describes conditions to be fulfilled, elementary theory, and approximations used in manufacture. Methods of calculating the axial intensity and factors affecting conspicuity are discussed.

Sector Flux, the Measurement of
H. D. EINHORN and K. R. ACKERMAN (W)
17 (2), 37, 1952

A new concept for the theoretical treatment of long linear light sources, which permits light distribution to be predicted from measurements on a single source.

Long Linear Light Sources, An Analysis and its Applications to Fluorescent Lamps

H. D. EINHORN (W)

16 (5), 101, 1951

A new concept "Sector flux" is proposed which should facilitate the calculation of illumination from long linear light sources, and a general theory of the long linear light source is given. The errors are assessed for three types of source in applying infinite source relations to finite layouts. The application of the results of the analysis to practical design is illustrated by a few examples of fluorescent lamp layouts.

Brightness Engineering

W. ROBINSON

16 (4), 61, 1951

Explains what is meant by "Brightness Engineering" in a preliminary discussion covering design procedure, establishment and application of brightness criteria. Describes recent American work in the light of which two methods of establishing a generalised brightness code are considered. Describes methods of brightness design and measurement.

Colour Rendering Properties of Light Sources, Measurement, Representation and Specification of Colour and

G. T. WINCH and H. R. RUFF (W)

16 (1), 13, 1951

States the problem and describes methods of measuring and specifying colour and colour rendering properties of lamps. Indicates typical forms of colour and spectral band specification. Describes new and accurate measuring apparatus enabling all the relevant data to be obtained by one apparatus.

Cinema Auditorium Lighting, an Investigation on the Level of Illumination required for Safe Movement

J. S. SMYTH (W)

15 (3), 92, 1950

Describes the first part of the investigations of a panel set up to study safety lighting in cinema auditoriums.

A Polar Distribution Calculator

H. V. SHURMER (W)

15 (3), 81, 1950

Describes simple graphical means of calculating the intensity distribution in a plane perpendicular to the axis of the source in any fluorescent lamp—specular trough fitting. Describes an instrument which facilitates the graphical work.

Metal Parts for Lighting Fittings, the Manufacture of

P. HARTILL

14 (7), 203, 1949

Reviews important properties of metals which are important in the lighting industry, and describes current methods of shaping and finishing. Discusses protective treatments in which regard is paid to corrosion resistance and light reflecting qualities. Performances of various metals and finishes are compared.

Lighting Glass, the Manufacture of
J. G. HOLMES
14 (7), 179, 1949

Discusses the properties and constitution of glass with reference to its use in lighting fittings. Compares optical principles of light control by reflection and refraction, and gives data for the photometric properties of white and coloured glasses. Indicates precautions needed in the design and construction of fittings using glass components.

Fluorescent Lamps, the Colour of
W. HARRISON
14 (6), 145, 1949

Discusses the relationship between special distribution and colour rendering properties of illuminants, particularly of white fluorescent lamps, and indicates the respective functions of lamp chromaticity and spectral quality. Chromaticity and light spectral-band data are given for the principal fluorescent lamp phosphors. Deals with the choice of fluorescent lamp colours for general lighting and recent trends.

Aerodrome Runways, Design of Contact Lights for
H. J. TURNER (W)
14 (1), 1, 1949

Describes methods of calculating the light distribution required from aerodrome runway contact lights, with special reference to foggy weather. Discusses the limitation on intensity and distribution imposed by mechanical and electrical conditions, and the relative merits of flush-mounted and elevated lights.

Department Store Lighting. Factors Influencing the Design
A. W. JERVIS
13 (9), 226, 1948

Discusses factors to be considered in store lighting. Use of various sources. Gives examples.

Decorative Lighting
L. H. HUBBLE
13 (8), 207, 1948

Discusses the use of light arc lighting effects to improve interest and appearance in addition to the functional use. Treats a particular installation in detail.

Some Frontiers of the Lighting Art
WARD HARRISON
13 (5), 121, 1948

Deals with problems in various fields still to be investigated and solved by lighting engineers with particular reference to illumination and brightness levels and distribution and the effects on ocular comfort.

The Lighting of Architecture
G. GRENFELL BAINES
13 (2), 23, 1948

Deals with the essential characteristics of and differences between architecture before and since the advent of modern light sources. Warns against attempts to simulate the various effects produced by sunlight. Considers lighting and decoration and the proper use of fittings for pleasing effects. Views are given on future possibilities.

Part IV: Lighting Practice and Applications

(Lighting for special applications; equipment; maintenance.)

The Lighting of Standard Factories on a Trading Estate
J. S. McCULLOCH
22 (2), 49, 1957

Compares the cost of using different light sources in the standard lighting installation developed specially for trading estate standard factories, taking into account the annual charges for wiring, fittings, replacements and power.

New Lighting Development in Germany
L. SCHNEIDER
22 (1), 9, 1957

Discusses the influence on development with particular reference to lighting, of the basic raw materials, standards of craftsmanship, etc., available in a country. Describes lighting practice in offices, shops, schools, theatres and churches, and deals with recent developments in railway lighting in Germany.

London Airport, Lighting at
J. G. HOLMES
21 (8), 179, 1956

Examines the lighting at the airport in detail from the point of view of the passengers, guidance and control of aircraft and the maintenance of services.

Colour Matching, Light Sources for
E. E. MILES and D. C. PEACH
21 (6), 135, 1956

Discusses requirements and preferred characteristics of sources for colour matching and observes variations. Describes characteristics of various artificial sources.

Floodlighting of Historical Buildings and "Sound and Light" Spectacles in France
JEAN CHAPPAT
20 (8), 243, 1955

Hazardous and Corrosive Locations in Industrial Plants, the Lighting of
A. G. PALMER and W. E. HARPER
20 (6), 179, 1955

Reviews British practice, amplifying Gt. Britain's report to C.I.E. Fire, explosion and corrosion risks discussed in relation to lighting and regulations summarised.

Maintenance of Lighting Installations
W. ROBINSON and J. W. STRANGE
20 (5), 157, 1955

Considers lamp replacement methods and their economics, deterioration of fittings of different kinds and concludes that maintenance should be a primary factor in lighting and fitting design.

Shops, the Lighting of Small and Medium
R. L. C. TATE
20 (4), 135, 1955

Deals with current techniques of window lighting including avoidance of reflections, and factors involved in interior lighting. Gives a survey of after-hours lighting in some representative shopping centres and a résumé of available lamps and equipment.

Home Lighting
A. H. YOUNG and C. J. MISSELBROOK
20 (1), 37, 1955

Reviews developments from 1928 to date, and attempts to show future progress. Large range of materials used in manufacture of luminaries for home use is discussed. Problems in lighting various rooms, and lack of interest in fluorescent lighting treated. Suggestions made for developments to encourage fluorescent lighting. Plea made for approvals system for domestic fittings to ensure safety. British, Continental and American practice compared.

Mines, Lighting and Visibility in
A. ROBERTS (W)
20 (1), 15, 1955

Describes some results of an attempt to approach mine lighting from aspect of visibility underground. Effects of visibility on efficiency and safety. Typical illumination and luminance levels described for various underground environments and details of visual tasks which occur in them.

The Economics of Four Industrial Lighting Installations
19 (9), 279, 1954

(1) A Hot Cathode Fluorescent Installation
S. T. CLARK

Describes the requirements of and choice of light source for woollen textile plants. Compares tungsten and fluorescent lamp installations in a practical test in a particular case.

(2) A Cold Cathode Fluorescent Installation
W. HOWE

Describes a lighting installation of a large engineering factory where high precision work is carried out, and where, because of shift working, artificial lighting is in almost continuous use.

(3) A High Bay Mercury Installation
F. JONES

Discusses the problems involved in lighting the crane shop in a large engineering works and analyses installation and operating costs of three lighting schemes on the basis of which 1,000-watt mercury-vapour lamps were chosen.

(4) A Blended Light Installation
G. W. S. LEVEY

Describes an installation comprising a mixture of mercury vapour and tungsten lamps in steel works.

Street Lighting in a Large London Suburb
A. T. DURBRIDGE
19 (9), 263, 1954

Describes provision of up-to-date lighting in a large residential and shopping area (Harrow) and discusses financial aspect.

Plant Growth, Artificial Lighting for
A. E. CANHAM
19 (8), 235, 1954

Discusses recent developments and summarises existing knowledge in this field. Gives basic data and describes installations.

Textile Production, Lighting for
H. HEWITT
19 (3), 61, 1954

Examines effect of developments since the war in lamps, equipment and lighting methods on visual conditions in textile industry. Special reference made to fluorescent lamps. Some installations having novel features are reviewed.

Fluorescent Dimming Circuits, Applications of
H. H. BALLIN and W. J. VINE
19 (2), 29, 1954

Surveys the use of fluorescent dimming for different lighting applications. Discusses new circuits, describes the lighting equipment and considers some uses of dimming in industrial lighting. Discusses the potentialities of fluorescent stage lighting and considers application to colour-changing flood-lighting, outdoor illuminations and display lighting.

Lighting in Australia and Europe
D. C. MACLURCAN
18 (7), 199, 1953

Reviews various aspects of lighting in Australia and compares them with European achievements in these fields.

Sports Lighting
M. W. PEIRCE
18 (7), 177, 1953

Discusses problems and requirements associated with lighting for indoor and outdoor sports. Deals at some lengths with football field lighting.

Power Station Lighting
P. D. FIGGIS
18 (3), 69, 1953

Discusses exterior and interior lighting problems in power station lighting, including the provision of emergency lighting.

Explosives Plant, Lighting in an
R. W. MIDDLETON and W. E. HARPER
18 (1), 23, 1953

Describes the lighting in a large British explosives factory.

Blended Light
S. ANDERSON
18 (1), 15, 1953

Discusses the use in industrial lighting of mixed light from sources having different spectral distributions.

Factory Lighting, Some Developments in
T. S. JONES
18 (1), 9, 1953

Discusses changes in lighting practice in factories over a period including mainly the war years.

Underwater Illumination, Problems of
W. D. CHESTERMAN and J. B. COLLINS
17 (8), 193, 1952

Discusses visibility and lighting problems under water, and describes instruments, sources and photographic methods applied, also application of flash discharge to special under-water problems.

Shipyards, the Lighting of
J. S. McCULLOCH
17 (5), 101, 1952

Examines the lighting for interior and outside areas and building berths. Typical installations are described and recommended illuminations given.

Buildings, the Lighting of
W. A. ALLEN and R. G. HOPKINSON
16 (7), 170, 1951

A summary of a paper read by the authors at a joint meeting of the Architectural Science Board of the Royal Institute of British Architects and the Society. Published in full in the R.I.B.A. Journal, April and May, 1951.

Gas Street Lighting, Recent Developments in
W. CRAWFORD SUGG
16 (7), 153, 1951

Details improvements and changes in low pressure gas street lighting equipment since the war, and refers to pre-war developments. Simplified maintenance has been achieved together with improved performance and more consistent operation. Describes the changes made in lantern and control gear design and reports full-scale test results for certain installations.

New House of Commons, Lighting of
C. DYKES-BROWN
16 (2), 29, 1951

Lighting in the new House is designed, with the other services, as an integral part of the building. In the debating chamber artistic requirements have been given first consideration, using new techniques where necessary. The main illumination is from cold cathode high voltage lamps in the laylight, the intensity being variable from zero to full value.

Colour Matching, Fluorescent Lamp Artificial Daylight Units for
G. T. WINCH, W. HARRISON and H. R. RUFF (W)
16 (1), 1, 1951

Considers the colour and colour-rendering characteristics of daylight and the requirements for artificial daylight sources for critical colour matching, and shows the two main lines of development of daylight fluorescent lamp units. These are fluorescent lamps, either hot or cold cathode, with a combination of phosphors and combined fluorescent and tungsten filament lamps. Describes practical units.

Floodlighting
R. O. ACKERLEY
15 (10), 335, 1950

Defines floodlighting. Deals mainly with outdoor floodlighting with particular reference to spectacular floodlighting of buildings. Gives the desirable characteristics of floodlighting equipment, and deals with the various factors influencing the choice and arrangements of fittings, and use of supplementary lights. Gives illumination data for various types of building surface. Analyses a typical installation in detail and discusses possible fields for the use of floodlighting.

Aircraft Carriers, Special Lighting Units for the Flight Decks of
H. H. MATTHEWS (W)
15 (9), 328, 1950

Describes the development of "Pillar Lights" which formed part of the equipment enabling aircraft to be landed on a darkened aircraft carrier.

Street Lighting, the Development of in Gt. Britain
J. M. WALDRAM
15 (8), 285, 1950

Traces the development of street lighting in Britain from the twenties to the present day. Emphasises six important stages in this development. Describes present notions of the theory of four systems—non-cut-off, semi-cut-off, cut-off and unidirectional, and reviews modern lanterns. States the outstanding problems of street lighting.

Stage Lighting in the Post-war Theatre in Gt. Britain
L. G. APPLEBEE
15 (8), 265, 1950

Explains the requirements of stage lighting and indicates some of the difficulties. Describes the various uses to which the many different types of apparatus are put, and the very elaborate control necessitated by user demands. The subject of colour is discussed and the application of electronic methods of control is described.

The Lighting of Fibre and Fabric
H. HEWITT
15 (7), 240, 1950

Reviews the application of lighting at all stages in clothing manufacture through to the finished garment. Industrial requirements are assessed, and observations made on interesting developments and possible future trends. Reference is made to the application of light sources to special tasks, including display of the products.

Lighting in Sweden 1940-50
IVAR FOLCKER
15 (7), 225, 1950

Describes lighting in Sweden under four headings: (1) Background information (historical, geographic and economic factors); (2) Lighting principles; (3) Interior lighting practice; (4) Some lighting investigations.

Fluorescent Lamps, the Dimming of and its Application to the Theatre
J. W. STRANGE
15 (4), 111, 1950

The development of methods of dimming now makes it practicable to utilise the colour range and efficiency of fluorescent lamps for stage lighting. Shows that a range of intensity of over 300 to 1 is obtainable, and that for coloured effects the efficiency is superior to tungsten filament lamps with subtractive filters, by from 2 or 3 to 1 to as much as 40 to 1.

Fluorescent Lamp Installations, the Operation and Maintenance of
W. A. R. STOYLE and G. D. JONES-THOMAS
15 (1), 1, 1950

Deals with lamp and circuit characteristics from a practical point of view to assist maintenance engineers in view of the many new lamps and circuits. Gives detailed descriptions of circuit components, recommended testing methods and advice on detecting, identifying and remedying troubles.

Hospitals, Specialised and General Lighting in
M. W. PEIRCE and D. J. REED
14 (10), 301, 1949

Discusses some of the lighting requirements in hospitals and describes ways in which they are satisfied. Operating theatre lighting is considered in some detail, and attempts to classify systems of lighting according to their suitability for different surgical operations.

Public Lighting in France and England at the Present time
L. GAYMARD
14 (8), 229, 1949

Deals chiefly with street lighting in France, but briefly mentions lighting of monuments and public buildings, and also of road tunnels. Distinguishes two main types of street lighting—urban and highway. Describes how various problems are tackled, present tendencies in lanterns and sources, control and maintenance.

Churches, the Lighting of
L. C. RETTIG
14 (5), 117, 1949

Discusses the illuminating engineering principles applicable to church lighting. The requirements of various denominations are discussed in conjunction with different styles and periods of architecture. Classifies illumination methods and associated fittings and indicates their suitability and limitations for a number of situations. Includes notes on historical aspects, light sources, installation and new projects.

High Speed Photography, Gas-filled Discharge Tubes as Sources for
J. W. MITCHELL (W)
14 (4), 91, 1949

Describes the development of high-intensity flash discharge tubes giving flashes with an effective photographic duration of less than 1.5 microseconds which permit photography of high-velocity shells by reflected light. Discusses properties and limitations in single and multiple flash applications.

Transport Lighting with Fluorescent Lamps
H. R. RUFF, J. N. HULL and R. V. MILLS
14 (3), 57, 1949

Analyses the problem in terms of requirements and limitations, and describes the characteristics of lamps and circuits, explaining the choice between direct operation and conversion to a more suitable electrical supply. After describing the new types of lighting and control equipment, gives a detailed account of the application of the systems developed to specific classes of vehicle, and the results achieved.

Photographic Illumination in Motion Picture Studios
F. V. HAUSER, F. S. HAWKINS and W. R. STEVENS
13 (4), 91, 1948

Describes the conventional method of lighting a motion picture set, the illumination levels and spectral distribution required, from which general requirements are deduced for fittings using tungsten filament, carbon arc and high pressure mercury vapour discharge lamps. Detailed account is given of the method of use of these sources to satisfy the requirements. Discusses optical, mechanical and thermal design problems. Indicates accepted good practice and lines of future progress. Discusses supplies, including noise in the carbon arc flame generated by supply voltage ripple.

High Voltage Fluorescent Tubes
H. G. JENKINS and J. N. BOWTELL
13 (3), 61, 1948

Discusses characteristics, technical data and materials used in these lamps, with special reference to the cold cathode type currently available. Deals with the various types of cathodes and the more important luminescent materials used.

Modern Flash Discharge Tubes, the Application of
C. R. BICKNELL
13 (1), 1, 1948

Defines flash discharge tubes as sources designed to produce flashes of high intensity and short duration. These may be isolated by relatively long time intervals or follow one another in rapid succession. Operating conditions result in light of good spectral quality and a duration capable of arresting very high speed motion. Discusses applications broadly with some particular examples.

Part V: Research and Development

(Research and development and basic physical properties of light sources and materials; tests; specification.)

Fluorescent Lamps, Some Factors Affecting the Efficiency of—The Quest for Higher Luminous Output
F. JACKSON, R. MOLLOY and K. SCOTT
21 (1), 10, 1956

Discusses theoretical aspects of light output by efficiency of production of ultra violet radiation and conversion by the phosphors into light. Reviews applications to lamp making.

Electroluminescence
J. N. BOWTELL and H. C. BATE
20 (7), 223, 1955

Deals with main features of the phenomenon, particularly aspects of interest to lighting engineers. Brief historical account given and design, construction and performance of electroluminescent light sources described. Specialised applications discussed and future uses indicated.

Lamps and their Uses
J. N. ALDINGTON
19 (10), 319, 1954

Mentions factors which have to be taken into account in evolution of new sources. Describes various types of lamp. Suggests that progress in near future will be largely improvements on existing lamps. Colour problems affecting development of fluorescent lamps mentioned.

White Rigid Polyvinyl-chloride Sheet, the Properties of
W. E. HARPER (W)
17 (7), 183, 1952

Reports photometric, thermal, mechanical and ageing tests on this new white diffusing material, which show it to have good photometric but limited thermal properties.

Luminescence as Applied to Lighting
H. G. JENKINS and A. H. MCKEAG
17 (7), 159, 1952

Deals with the features of the subject of interest to illuminating engineers. Describes the theoretical aspects of photoluminescence and mentions important phosphors. Refers to electroluminescence.

Fluorescent Lighting Fittings and Components, Specification and Testing of
G. FAHEY, D. T. WAIGH and W. R. BLOXSIDGE
17 (6), 131, 1952

Discusses problems involved in specifying performance of fluorescent lamps and associated control gear, both in "free air" and in fittings.

Gas Arc Condition, the Extension of
H. W. CUMMING
16 (6), 129, 1951

An introductory section in which the derivation of the term "Gas-arc" is indicated is followed by data on arc discharges through the various rare gases. The work providing the data has led to a new, 1-kw., Xenon lamp. Discusses the possibilities of operating high wattage high brightness sources and indicates applications for several types of gas arc discharge lamps.

Air-Cooled High Intensity High Pressure Mercury Vapour Lamps
V. J. FRANCIS (W)
15 (9), 315, 1950

Important developments during and since the war in high pressure mercury vapour lamps have resulted in greatly increased knowledge of the properties of lamps with high power loading per centimetre of arc. As well as progress with small high brightness sources, a new design between these and the old tubular lamps has appeared with higher luminous efficiencies than obtainable previously. Progress in colour rendering has led to new applications.

Acrylic Enclosures for Flameproof Lighting Equipment
P. H. COLLINS and W. E. HARPER
15 (5), 137, 1950

Describes investigations of mechanical, thermal, optical and other physical properties of the acrylic plastic polymethyl methacrylate, used for the enclosures in many flameproof lighting fittings used in large-scale coal-face lighting trials. Performance data have been obtained which should enable the drafting to commence of a British Standard covering the design of methacrylate enclosures for flameproof lighting fittings.

The Gas Arc—a New Light Source
J. N. ALDINGTON
14 (2), 19, 1949

An introductory section is followed by consideration of the factors influencing the development of the Gas Arc—a term applied to a recently developed range of Xenon-filled discharge tubes operated under conditions causing them to emit an intense radiation of sunlight quality. Gives luminous and other characteristics and circuit arrangements for ignition and maintenance. Describes the latest developments and examines possible applications.

New Lamp Developments
N. L. HARRIS
13 (7), 181, 1948

Traces improvement in luminous efficiency of lamps from early sources to present gas-discharge lamps. Describes characteristics of these last types. Indicates lines of further improvements.

Acrylic Plastics in Lighting
W. E. HARPER and H. P. WALKER
13 (6), 147, 1948

Reviews range of materials, properties, fabrication techniques and application in luminaries.

Fellowship

The Council has accepted the following application for Fellowship of the Society:—
Mr. John Reid

Diploma Membership

The Council has accepted applications for the Society's Diploma in Lighting Engineering from the following, who are now Diploma Members:—

Mr. K. R. Ackerman
Mr. A. G. Brown
Mr. R. A. Chappell
Mr. T. B. Coles
Mr. W. B. Dinwoodie
Mr. R. J. Fothergill
Mr. A. M. Gummer
Mr. T. H. Gurney
Mr. J. S. Hart
Mr. D. H. Holloway
Mr. L. F. Needham
Mr. M. F. Oldham
Mr. H. W. Rooke
Mr. B. Ruston
Mr. D. Scott
Mr. J. E. Smith
Mr. J. S. Tomlinson
Mr. G. M. Whittle

Additions to the List of Members

The following applicants have been duly elected by the Council to membership in the Society:—

Sustaining Member:—

Erinoid Ltd. ..... *Representative*: K. P. R. Watkins.
Stroud, GLOUCESTER.

Corporate Members:—

Abboud, J. J. ..... Philips Liban S.A. P.O. Box 670, Beirut, LEBANON.
Bonner, G. G. ..... 82, Bernadette Avenue, Anlaby High Road, HULL.
Caddick, D. J. ..... 60, St. Johns Road, Kates Hill, Dudley, WORCS.
Cain, A. L. ..... 113, Melbourn Road, Royston, HERTS.
Cain, C. C. D. ..... 113, Melbourn Road, Royston, HERTS.
Camm, W. G. ..... Fearfield Buildings, Broadway, NOTTINGHAM.
Carrington, H. M. ..... 302, AA House, Queen Victoria Street, Cape Town, SOUTH AFRICA.
Cassidy, B. J. ..... 15, Portobello Harbour, Dublin, IRELAND.
Castlo, C. A. ..... 160, Hillside Crescent, Cheshunt, HERTS.
Clark, G. ..... British & Dominion Engineering (Pvt.), Ltd., P.O. Box 1628, Salisbury, RHODESIA.
Constantinou, A. M. ..... C/o Electricity Authority of Cyprus, P.O. Box 186, Larnaca, CYPRUS.
Hardy, J. S. ..... 9, Sixth Avenue, Burwood, Victoria, AUSTRALIA.
Hesselton, S. M. ..... 25, Dickens Street, Elwood, S.3, Melbourne, AUSTRALIA.
Jones, F. M. ..... 3, Greenway Road, Timperley, Altrincham, CHESHIRE.
Kelly, B. P. ..... Siemens Edison Swan Ltd., 38, Upper Thames Street, LONDON, E.C.4.
Kenyon, B. G. ..... 69, Priory Grove, Gipsyville, HULL.
Lawlor, G. W. ..... 18, Cremore Park, Glasnevin, Dublin, IRELAND.
Maddock, E. G. ..... 26, Hornsey Lane Gardens, Highgate, LONDON, N.6.
Mason, S. E. ..... "Brackenrigg," Wilson Street, Anlaby, EAST YORKS.
Maughan-Brown, K. R... 302, AA House, Queen Victoria Street, Cape Town, SOUTH AFRICA.
Morton, F. ..... 13, Robey Street, Page Hall, Sheffield 4, YORKS.
Parr, T. J. ..... 5, Woodville Road, Harborne, BIRMINGHAM 17.
Pask, A. L. ..... 1, Tetney Close, Ermine West, LINCOLN.
Price, P. J. ..... 4, Thanet Road, Bilton Grange Estate, HULL.
Rowe, D. C. S. ..... Lumenated Ceilings Limited, Alliance House, 12, Caxton Street, LONDON, S.W.1.
Savell, A. L. ..... P.O. Box 2018, Johannesburg, SOUTH AFRICA.
Smith, F. ..... 52, Halesden Road, Heaton Chapel, Stockport, CHESHIRE.
Tarrant, A. W. S. ..... 198, Uxbridge Road, Hampton Hill, MIDDLESEX.
Toomey, J. J. ..... 10, Bawtry Road, Whitehall, Dublin, IRELAND.
Uys, J. F. ..... Dept. of Electrical Engineering, University of Stellenbosch, SOUTH AFRICA.
Webb, S. W. ..... 2, Oakham Crescent, Dudley, WORCS.
Woodham, W. J. ..... 161, East Lane, North Wembley, MIDDLESEX.

Student Members :—

Dobson, Miss V. F. ..... "The Star Inn," Main Street, Willerby, Nr. Hull, YORKSHIRE.
Graham, Miss M. ..... 7, Howkins Road, Brownsover, Nr. RUGBY.
Groombridge, P. ..... 16, Scalby Avenue, Newby, Scarborough, YORKS.

Transfer from Student to Corporate Membership :—

Stainthorp, J. R. ..... 7, Station Lane, Greatham, West Hartlepool, Co. DURHAM.

Binding of Transactions

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The binding is in dark green cloth and gold lettering. The index to Volume 22 is enclosed with this issue and should be sent with copies of the Transactions to the binders.

End of Volume and New Format

This issue (No. 10) completes Volume 22 of the Transactions of The Illuminating Engineering Society.

In future Transactions will be published quarterly in a new format the first issue of which will be published about April next.

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